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THE IMPLEMENTATION of INDUSTRIAL DEVELOPMENT PROGRAMMES using CRITICAL PATH NETWORK THEORY

by

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SUMMARY

The implementation gap.

The complexity of industrial development planning and programming processes is contrasted with the even greater complexity of integrated, dynamic implementation of such plans, and a serious "implementation gap" between planners and implementors is exposed.

Purposes of paper.

The paper demonstrates use of Master Plan (Critical Path) Networks in bridging the "implementation gap", and seeks to motivate its application as a pilot project in some developing country.

Illustration of critical path network application.

A hypothetical regional development problem and a programme for industrialization are postulated. The requirements of implementing a sugar industry project within the programme are outlined. Basic concepts pertaining to aggregate activities, events, dummies, and arrow-diagram networks are explained. Ten basic steps for using critical path network theory at the highest level, for implementation of the Sugar Industry Project are illustrated and discussed in detail. The advantages of involving the next lower level of supervision in the implementation planning and programming process is discussed. The applicability of networks in dynamic implementation processes is evaluated. The desirability of using computer programs to expedite the analysis of complex

networks, but only after network analysis is thoroughly mastered manually, is emphasized. Eventually a major breakthrough in implementation systems and processes may be effected in the developing countries.

Introducing critical path networks to programme-implementation.

Acceptability at the top level of planners and implementors is regarded as absolutely essential. The compiling of a Manual on the Use of Networks in Implementation, based preferably on actual experience on a pilot project is presented as the best means for educating at all levels.

Further research in dynamic implementation.

Some possibility for treating the various interdependent projects in any programme as a network of interlocking investments, each with its own possibly uncertain and variable gestation period, is pointed out as a possible fruitful avenue of further research with aggreagte simulation models. Model-experimentation with alternative economic policies and implementation strategies would help evolve and set up sound dynamic implementation systems and processes. Integration of individual project networks to evolve a Comprehensive Master Plan for Development is illustrated in an appendix.

THE IMPLEMENTATION GAP

Development planning a complex process.

If one even skims through any detailed comprehensive plans for economic development, which are now very much in vogue, one is left with no doubts whatever as to the enormity and complexity of the task of integrated economic development planning and programming. One quickly appreciates the complicated processes involved which call for meticulous attention to detail on the part of experts in every field. Overall social, economic and cultural goals are specified. A great deal of detailed information is provided for all sectors of the economy from production output targets to inputs required by way of investments in money, man-power, machines, material resources and every human endeavor required to harness these resources. Broad guide-lines for domestic consumption and hopefully consistent economic and fiscal policies are proposed for realizing the domestic savings and foreign exchange required for achieving the levels of investment called for. Details of public works projects geared to programmes for agricultural and industrial expansion required to improve opportunities for employment and to achieve other objectives of the plan are often outlined as well. Hopefully all such endeavors will be carried forward successfully toward achieving the ambition of ultimate economic self-sufficiency which national pride demands.

Dynamic implementation process even more complex.

However, even merely skimming through such a detailed and comprehensive plan, leaves one with little doubt that the task of continuously implementing even a comparatively simple development plan would present,

in many ways, a more complicated and formidable task than that of drawing up the plan itself. The most carefully designed and elaborate plans, or for that matter even simpler ones, can be ruined if they are not implemented on schedule, economically and efficiently. Successful, dynamic implementation calls for close and continuing collaboration between the planners and the diverse kinds of practical men and experts in professional, administrative and technical cadres who are responsible for "getting the job done", in all sectors of the economy; continually getting the most in productivity and efficiency throughout all phases and at all levels of plan execution, by integrated and comprehensive implementation planning and programming, cost control, and performance evaluation, through: (1) effective organization and communications in defining and assigning responsibilities; (2) efficient co-ordination of the diverse interdependent activities in the several different sectors and sub-sectors of the economy; (3) the use of realistic criteria for the timely evaluation of performance and overall progress; (4) the timely anticipation of problem areas like unforeseen delays, manpower and resource discrepancies, and the taking of appropriate and timely remedial action; (5) the improved evaluation and allocation of available scarce resources; (6) the timely revision of policies, priorities, and resource allocations, as contingencies demand; (7) realistic budgeting for the overall programme and its incorporation into the national, annual budget, as well as meaningful budgettory control based on progress and performance; and in short every conceivable aspect of the day-to-day business of managing any purposeful national endeavor from top to bottom,

all the way from the start on a continuing basis.

Scanty treatment exposes "Implementation Gap".

Even a very close study of these same detailed development plans however, generally fails to reveal just how the complex dynamic process of plan implementation will be started-up and sustained, throughout the life span of the plan, as well as of succeeding plans, on a continuing, year-to-year and month-to-month basis. Therefore, the writer thinks that all development plans fail to treat the process of development planning, programming and implementing as a continuing, dynamic process. Further, scores of volumes have been written on the theory of economic development and its application to the developing countries, while literature on the implementation of development plans is virtually impossible to find.

The scanty literature that does exist on the implementation of development plans, merely points to the urgent problem that implementation presents in the developing lands and tends to treat plan implementation as a collection of hopefully consistent economic and fiscal policies that have been designed to achieve the goals and objectives of a development plan. No cohesive theory has yet been propounded for treating analytically the diverse ramifications of the managerial problems involved in implementing policies and evaluating their overall impact in achieving planned goals and objectives on a continuing basis, or for setting up dynamic implementation systems in a socio-economic environment that is being subjected to, and wracked by, powerful political forces that are attempting to change that environment rapidly. Hence, current development

planning seems to fail to recognize dynamic plan-implementation as the vital, indispensable link between socio-economic goals and the functional realities of achieving them. Consequently, a gulf has been produced between the plan and its implementation, between development theory and practice, between planners and implementors, between objectives and achievements, between efforts and results. In the writer's opinion, this critical gulf in the development process constitutes the "implementation gap".

Purpose of paper.

This paper aims to the point towards a theory for bridging the "implementation gap", thus providing the medium whereby the planners and implementors can communicate and collaborate with each other readily and effectively, on a continuing basis. Every development plan could as well be provided with a tentative implementation plan, which would form the basis for systemmatically initiating and carrying forward all those diverse dynamic functions that were pointed earlier as essential in order to achieve plan-objectives. This implementation theory and tentative implementation plan would obviously change and evolve as the social, economic, and political realities of life dictate.

A secondary, but no less important, prupose is to motivate some developing country to start a pilot project in which critical path network theory, which is expounded and explained in this paper, would be applied at the highest levels of planning for implementation. Such a pilot project could be designed to supplement present planning, programming and implementation practices while attempting to serve as a comparative

study aimed at improving present implementation systems and processes wherever possible. The practical experience gained on such a pilot project would lead to the compiling and publishing of a Handbook, or Manual on the Implementation of Industrial Development Programmes using Critical Path Network Theory, which would then be available for use in all developing countries.

The comparatively simple but hopefully imaginative example which has been devised for the purposes of this paper will now be illustrated.

ILLUSTRATION OF CRITICAL PATH NETWORK APPLICATION TO AN INDUSTRIAL PROJECT

Purposes, hopes and contentions.

This paper aims, as its principal purpose, to illustrate the application of critical path network theory to the implementation of a specific industrial development project, within the context of an integrated programme for industrialization. For this illustrative purpose a comparatively simple, but hopefully imaginative, example has been devised to demonstrate the practical application of network theory to industrial project implementation. The example has been based partly on actual feasibility studies conducted in a developing country. The specific industrial development project selected in the detailed illustration permits the basics of critical path network theory to be demonstrated clearly and simply. The example is aimed at appealing to all levels of responsibility and classes of persons who are involved in, and concerned with, industrial development. Such persons include not merely those involved in the practical planning, programming and implementation phases of industrial development plans, but also those confined to the purely theoretical and conceptual aspects of planning and policy-making for industrial development. Hopefully, the detailed illustration incorporates sufficient realism and practical simplicity, to stimulate each reader to give full play to his imagination in appreciating the potential applicability of critical path network theory in his own special area of work. The writer contends that the theory must first be appreciated, accepted, and applied at the highest level of policy-making and planning for development if any worthwhile

results are to be achieved from its use. However, in order that the theory be applied more and more successfully at the highest level, the co-operation of at least the next lower level of responsibility for implementation would become progressively more and more desirable and necessary. Therefore, this paper has been written to appeal to the widest possible audience and designed to stimulate thereby the rapid evolution, indigenously, of the dynamic implementation systems that are so urgently needed in the developing countries.

The development problem.

The illustrative example hypothesizes the tropical island of Nabropat, whose economy is precariously dependent on the export of primary agricultural commodities. The island's ten million people, increasing at about 2.5% annually, eat rice as their staple food. About one half of the island's food requirements are imported, causing a considerable drain on foreign exchange earnings. A very sparse population inhabits the malaria-ridden, flood-ravaged, south-eastern part of the island, which is also the least developed economically. Fertile and extensive rice lands are left uncultivated, due to the lack of adequate irrigation facilities, cheap fertilizer, and perennial flood-damage. Historically the region was amongst the more flourishing and populated several centuries ago. The Ali River and its tributaries floods large areas of the region annually, causing extensive damage to food crops and property, and contribute considerable to the high incidence of malaria; all resulting in the steady deterioration of, and slow exodus from, the region. However, comprehensive studies indicate that: (1) the Ali River

and its tributaries can be harnessed by building a dam in the highlands at Ginia; (2) extensive rice, food-crop and sugar-cane cultivation can be undertaken by a much larger population than now inhabits the region, if the perennial floods can be eliminated; (3) the exploitation of natural mineral deposits offer excellent prospects for manufacturing cheap fertilizer economically and profitably, if road and rail transport facilities are improved and extended, and cheap electricity made available; (4) hydro-electricity could be generated at Ginia to provide not only all the electricity required to operate sugar, and fertilizer factories, but also for the eventual domestic electrification of the entire region; (5) the port of Santia could be improved to become a major centre for developing a modern fishing industry extending over the entire south-eastern coast of the island; (6) the provision of cheap electricity for purposes of refrigeration, would enhance the development of a fish and food canning industry as well as an industrial estate near Santia.

An integrated industrial development programme - the solution.

The government of Nabropat has decided to include an industrial development programme for rehabilitating its S.E. region, in the island's comprehensive ten year plan for economic development. The plan sets the following specific projects as the means to developing the land, increasing food-production, encouraging immigration, enhancing employment-prospects, raising living-standards, and generally stimulating the development of vigorous, healthy communities in the region: (1) the harnessing of the Ali River, in order to eliminate floods and the malaria-sourge for

all time; (2) the provision of irrigation water in order to encourage rice and food-crop cultivation, and minimize present food imports; (3) the cultivation of sugar-cane, in order to establish a sugar industry and eliminate substantial imports of sugar; (4) the establishment of a fertilizer industry, in order to supply all the fertilizer needs of the region at least; (5) the generation of hydro-electricity, in order to supply the needs of the sugar and fertilizer industry, encourage modern fish-refrigeration and food-canning industries, and the development of an industrial estate, as well as to promote the domestic electricication of the region as early as possible; (6) the improvement and development of the port facilities at Santia, in order to encourage the development of modern fishing industry and attract foreign shipping as well.

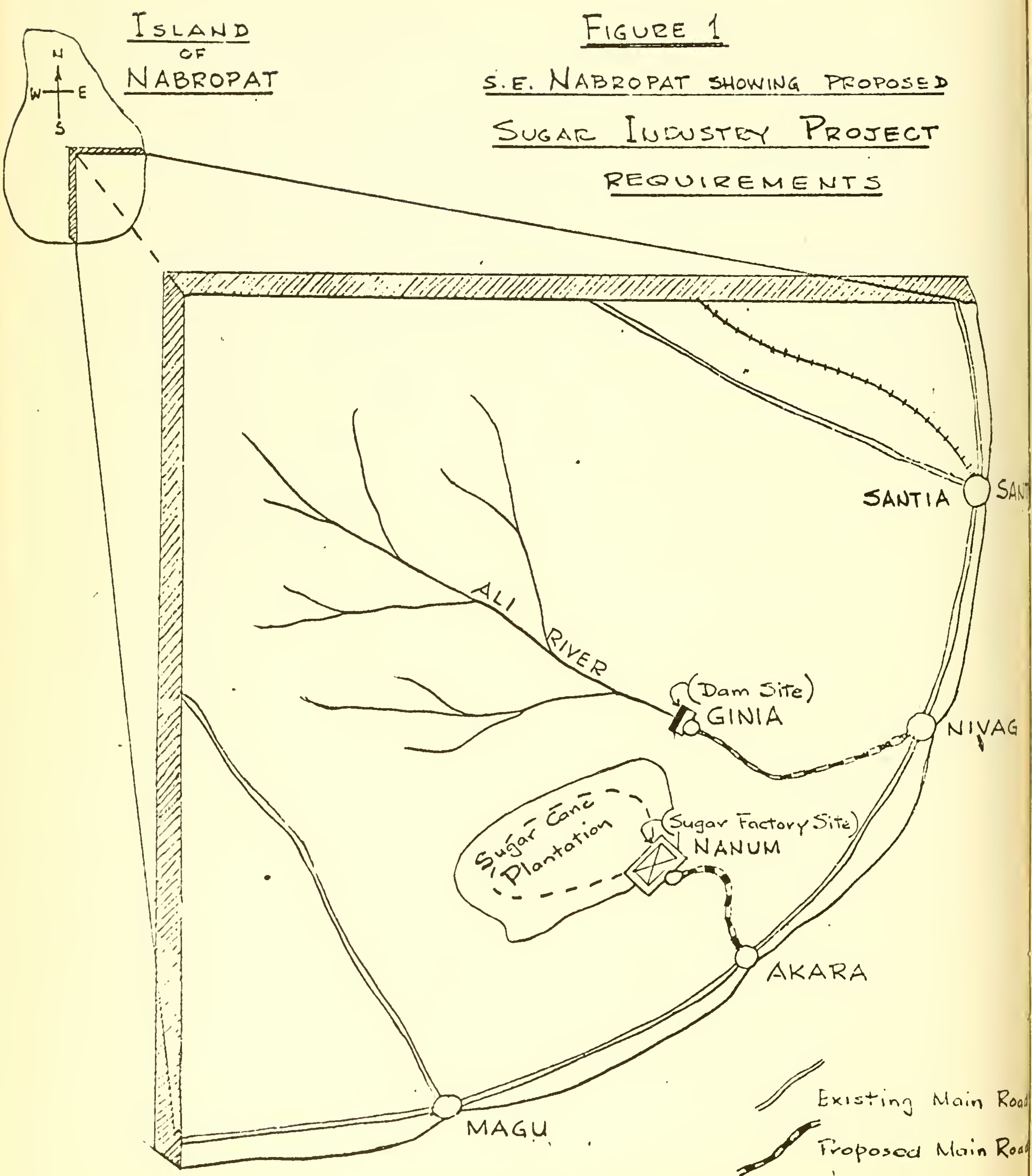
General pre-requisities to the implementation stage.

Several major preparatory studies must be made, and other basic requirements fulfilled, before any well-conceived integrated industrialization programme can reach the implementation stage. Since this paper aims primarily at demonstrating the use of critical path network theory in implementing an industrial development project, these preparatory studies and basic requirements will not be discussed or explained, but merely listed here. Such major pre-requisities will include the satisfactory completion of detailed studies, and their acceptance by the government of Nabropat, confirming: (1) the economic and technical feasibility of the integrated industrial development programme for the region; (2) the surmountability of the social and psychological problems involved in motivating large numbers of peasants

and town-dwelling, worker families, as well as the families of diverse skilled personnel, to move into the region permanently, in order to build a new life, in a new environment; (3) that the financing of the programme is sound and compatible with the long-term financial plans for developing the rest of the country; (4) that the limited numbers of administrative technical and other skilled personnel available in the country are adequate for the progressive implementation of the programme; (5) that the necessary expert technical personnel are availa ble at reasonably short notice from international agencies abroad; (6) that the necessary capital equipment and heavy machinery are readily purchasable abroad without undue delay; (7) that the key institutional, procedural, and substantive elements in the region's industrial development strategy do not conflict with the country's overall economic development strategy; (8) that all major policy-making stemming from the foregoing pre-requisities and other major functions of government have either already been taken, or will offer no serious obstacles where they have not. However, any serious failure to satisfy many of the foregoing pre-requisities completely, will be exposed early enough by using critical path networks in planning and programming for implementation, to permit timely, appropriate action to be taken and prevent possibly serious blunders and disruption of the smooth implementation process.

Sugar industry project implementation requirements.

For the demonstrative purposes of this paper only the implementation-requirements of the Sugar Industry Project using network theory, will be discussed and illustrated here in detail. The implementation-implications of the entire integrated industrialization programme will be illustrated


ISLAND OF NABROPAT
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E
S
FIGURE 1
S.E. NABROPAT SHOWING PROPOSED SUGAR INDUSTRY PROJECT REQUIREMENTS
SANTIA
ALI RIVER
(Dam Site)
GINIA
NIVAG
Sugar Cane Plantation
(Sugar Factory Site)
NANUM
AKARA
MAGU
Existing Main Road
Proposed Main Road

and briefly discussed in an appendix, in order to show the applicability of network theory to the overall programme for the S.E. region, as well as to the entire development plan for Nabropat.

The Sugar factory will be built at Nanum, as close as possible to the sugar-cane plantation. A major road would have to be constructed to the factory site from the closest town of Akara, which lies on the main route from Santia to Magu, as shown in Figure 1. The sugar factory should have a capacity for producing 100,000 tons of granulated sugar annually. Such an output is estimated to require a sugar-cane plantation of about 25,000 acres, plus about 10,000 acres for roads, building, dwelling, etc. Most of the potentially cultivable sugar-cane land can be cleared and prepared for cultivation only after secondary plantation roads have been constructed. Irrigation canals and suitable reservoirs are required before the actual cultivation can commence. Much of the water for irrigation would come from the reservoir created by damming the river.

Perhaps the most important undertaking of all would be presented in the motivation of people to move into the new, strange environment and begin a new life, while facing up to all the difficulty that such migrations entail. Willing families have to be selected and educated to provide the workforce required to cultivate, harvest and transport the cane to the factory. These worker families require housing and other community facilities, which they could be encouraged and organized to build on a self-help basis. Several plantation auxiliaries such as fertilizer, agrilcultural lime, pesticides, transport and harvesting equipment, have to be procured and supplied at the appropriate times, along with water for irrigation, in order to ensure adequate supplies

of cane of the right quality. The sugar factory and other buildings have to be built before the sugar-cane processing machinery can be installed and supplied with water and power for testing out, prior to start-up and production of sugar. The processing machinery and equipment, as well as the transport and harvesting machinery would have to be procured abroad, imported and shipped to the site. Similarly, all Sugar Mill Auxiliaries, such as fuel oils, chemicals, packaging materials must be procured and transported to the factory.

Perhaps the most critical undertaking of all is presented by the selection, motivation and training of the engineers, educators, administrators, medical and technical personnel and others required to provide the minimum basic skills essential for operating industry as well as organizing the smooth social, economic and cultural development of the entire S.E. region, on a permanent basis.

Basic concepts of activities, events, arrow-diagram networks, and dummies.

Just as implementing any integrated industrial programme calls for the implementation of a number of industrial projects, implementing an industrial project calls for the execution of several different types of jobs or activities. Some activities may be performed concurrently while others can be performed sequentially only after certain other activities have been partially or wholly completed. This activity-interdependence depends on the nature of the project as well as the physical contribution of each activity towards project completion. The activity breakdown structure depends primarily on the level of responsibility at which the implementation planning and programming is being considered

and conducted. At any given level of responsibility, similarly related activities may be aggregated and assigned to an individual supervisor who would be responsible for their overall execution. Thus the concept of an aggregate activity composed of several sub-activities at a given level of responsibility in the implementation process may be visualized. In the rest of this paper, "activity" would always imply "aggregate activity"; the word "aggregate" being often dropped for economy in words.

An activity, however, complex, must have a beginning and an end. Except for the very first activity, or activities, the commencement of any activity depends on the completion of one or more preceding activities. The completion of such a preceding activity, or group of activities, usually represents the achievement of a definite stage in the implementation of a project, as distinct from the activities that precede the achievement of that stage, and is called an event, or milestone. An event, or milestone, is not reached until all preceeding activities in the group, if more than one activity is involved, have been completed. No succeeding activity can commence until its preceding event has been reached. An event and its preceding group of activities are said to constrain activities that succeed the event. Every activity must commence with an event and end with another event. Activities are represented by full-lined arrows, and events by circles, or rectangles if more convenient. Circles at the tail and head of an arrow indicate the commencement-event and the end-event respectively, for any particular activity. Hence, the implementation of an industrial project, or

program, may be completely represented by a network of arrows and cirlces, appropriately laid out to indicate the concurrent or sequential interdependence between activities. Such a network of arrows and circles is called an arrow diagram network, and serves to identify every single activity in the network uniquely, by reference to a pair of beginning and end events. Obviously time elapses in performing all activities. In some situations events may be interdependent although no specific activity relates them. In such situations an activity requiring zero time to perform, called a dummy activity, is used to show the interdependency. All these concepts will become clear as the actual example of this paper is presented and explained in detail.

Basic steps in applying critical path network theory.

Given the basic background information and general requirements for implementing the sugar industry project, and the foregoing basic concepts, we can now proceed to apply the critical path network theory towards planning and programming the implementation of the project. The process proceeds in several distinct steps as follows: (1) list all aggregate activities to be performed in implementing the project, in any random order that they come in mind; (2) arrange all these aggregate activities into an arrow-diagram network, proceeding backwards from end to beginning to produce a tentative network defining the logical sequence in which the activities must occur; (3) number the events in the network systemmatically using an ordered numbering system such that the end-event number always exceeds the commencement-event number for every activity in the network; (4) assign durations and direct

costs for the completion of each activity both, at the normal pace as well as at the fastest pace, wherever possible; (5) determine the longest path, or critical path, which identifies the critical activities and events that control successful completion of the project for normal activity durations; (6) contract the network to shortest overall project duration at lowest possible increase in direct cost, working from the critical to sub-critical paths in turn by using the rapid durations and their corresponding direct costs; (7) determine variation of total project cost with overall project duration as well as the "optimum" overall project duration which gives minimum total project cost, by including all indirect costs as well; (8) expand the network of step (6) above, to the "optimum" overall project duration, at the highest possible decrease in direct costs; (9) for "optimum" overall project duration, re-allocate other resources in men, machines, and materials in order to improve the allocation of these resources and effect greater economies in project implementation and obtain a Master Plan Network for project implementation; (10) alter Master Plan Network in accordance with the foregoing steps as required by periodic reviews, revisions, contingencies and unforeseen circumstances. The application of these steps to the selected sugar industry project will now be explained and illustrated in detail.

First step lists aggregate activities.

As a first step we list all the aggregate activities that must be performed in implementing the Sugar Industry Project. Such a list might seem trivial and obvious after it has been compiled. This seemingly

TABLE 1

FIRST STEP IN SUGAR INDUSTRY PROJECT

IMPLEMENTATION-PLANNING PROCESS

Activity Identity	Descriptive List Of Aggregate Activities	Duration Months
A	Approve budgets to initiate appropriate action on the basis of departmental estimates, consultant's reports, feasibility studies etc., as recommended by the Economic Planning Commission.	3
B	Finalize detail plans for road from Akara to Nanum, negotiate and contract.	4
C	Finalize detail plans for Sugar factory, buildings, community facilities, transportation plans and contract.	6
D	Finalize detail plans for sugar-cane plantation, survey, land-acquisition, land-preparation and contract.	6
E	Select and train key personnel such as Administrators, Engineers, Educators, Medical Personnel, Technicians, Foremen, etc., and transport.	12
F	Select, educate, and transport agricultural workers and families.	12
G	Procure factory auxiliaries: - Fuel-oils; Lubricants; Chemicals: zinc, soda ash; Packaging Materials: jute sacks, paper, cardboard, plastic bags, etc.	4
H	Procure factory machinery and processing equipment abroad, import and ship to Akara.	12
I	Procure plantation auxiliaries: - Fertilizer: sulphates, phosphates, potash, urea; agricultural lime; pesticides etc.	4
J	Construct secondary plantation roads.	6

simple first step must never be omitted, since it would be very easy to take certain items for granted, or forget other indispensable ones. As a practical procedure, the Project Manager, might draw up a tentative list and request all his principal supervisors to examine the list for possible omissions and simplifications. After suitable modifications, a final listing would be arrived at. Such a listing for the present example is shown in Table 1. Close scrutiny reveals that several diverse departments and expert skills are seen to be involved, covering such fields as: (1) civil, mechanical, chemical and electrical engineering; (2) agriculture; (3) social and political science; (4) architecture and urban planning; (5) education; (6) transport; (7) land reclamation; (8) irrigation; (9) surveying; (10) foreign trade; (11) finance; (12) medicine; and (13) economics, among others. Unless careful judgement is exercised by the Project Manager, one or more of these departmental skills may easily be left out during the early stages of implementation planning and programming. Important channels of communication would be established at this first step stage of the implementation planning process, between the Project Manager and all other relevant departmental chiefs, if this first step is fully appreciated and handled expeditiously and tactfully. Such communications would prove invaluable in the next step of implementation of the entire project as well. The list shown on Table 1 explains itself effectively. It must not be regarded as typical of any similar project, but merely designed to facilitate this illustration of Critical Path Network Theory. Every activity has been assigned an identifying letter for later use, and

Table 1 (continued)

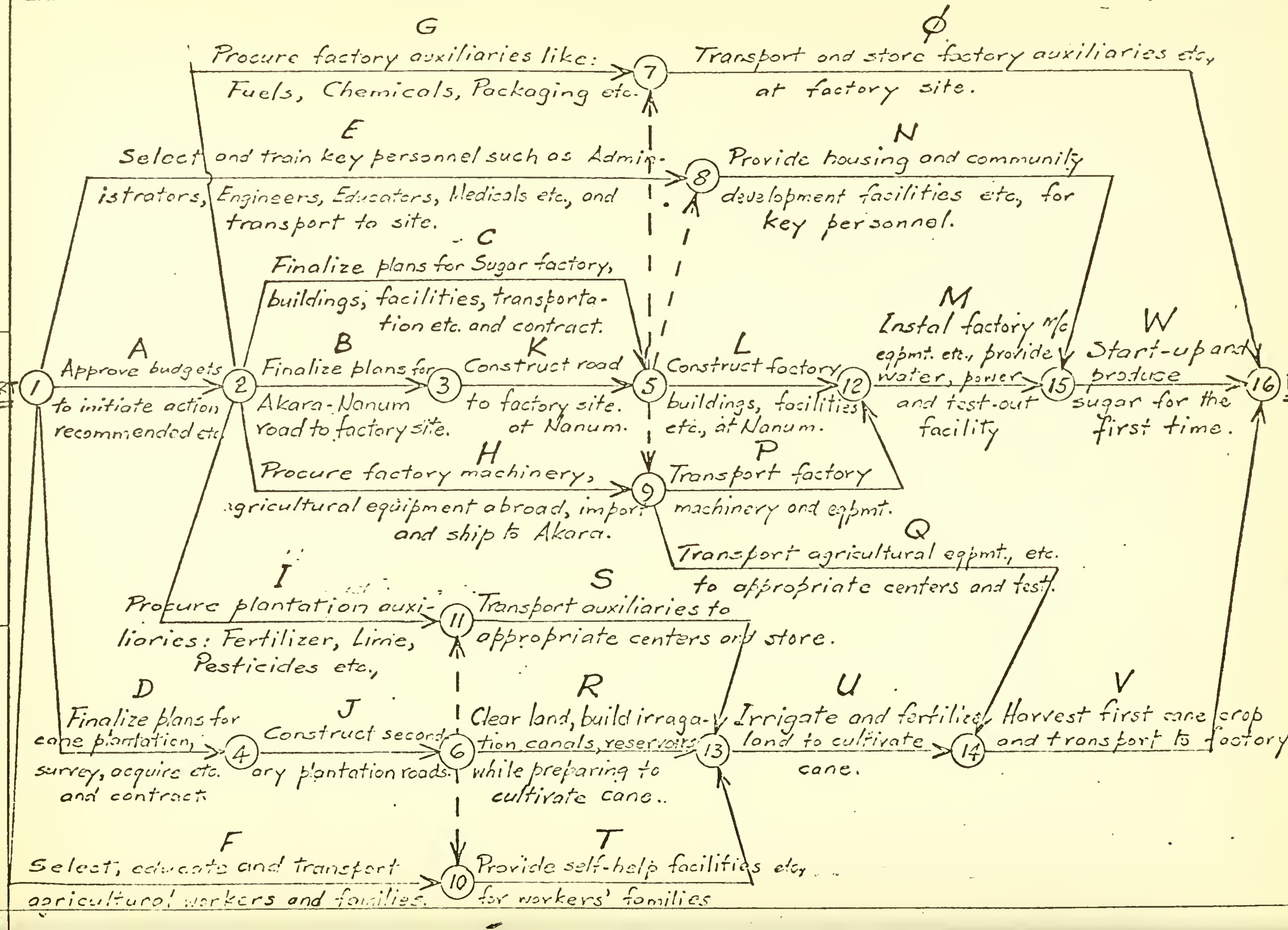
Activity Identity	Descriptive List Of Aggregate Activities	Duration Months
K	Construct main road from Akara to Nanum, the factory site.	6
L	Construct factory buildings facilities at Nanum.	12
M	Install machinery and equipment in factory; provide power, water supply, and test.	9
N	Provide housing, facilities etc., for key personnel's community development.	12
O	Transport and store factory auxiliaries at site.	3
P	Transport factory Machinery and Equipment to Site.	3
Q	Transport harvesting machinery and other agricultural equipment to plantation centers.	3
R	Clear land, build irrigation canals, resérvoirs, etc., while preparing land for cultivation.	12
S	Transport sugar-cane plantation auxiliaries to appropriate centers and store.	3
T	Provide self-help facilities to encourage housing and community for worker families at suitable centers.	12
U	Irrigate and fertilize land to cultivate cane.	6
V	Harvest first sugar-cane crop and transport to factory for processing.	3
W	Start-up and produce sugar for first time.	6

given a brief description. An estimate of activity-duration has been included tentatively. Such an estimate is not at all required in this first step, though it might be useful.

Second step constructs network, proceeding backwards.

The second step of constructing the arrow-diagram netowrk actually proceeds backwards from the end desired goals, namely "Start-up and produce Sugar for the first time", identified as activity W in Table 1, all the way back to the first activity, or activities, that must be performed at the start of the project implementation, namely, "Approve budgets to initiate appropriate action....as recommended by Economic Planning Commission," identified as activity A in Table 1. This process of working backwards from "End" to "Start", proceeds in the exact reverse of the sequence in which the activities would be performed in reality. The network could as well be constructed by working forwards from "Start" to "End", since the list of activities of Table 1 has already been compiled. However, experience has shown that the reverse process of successively figuring out all the important pre-requisities and pre-conditions of any given activity or event, starting from an end-desired goal, is more fruitful in revealing possible omissions in the list of Table 1, and less confusing than that of figuring out what must succeed any activity in order to achieve a desired goal. Application of Step 2 to the labelled network of Figure 2, entitled Tentative Network for Implementation of Sugar Industry Project in S.E. Nabropat, will now be discussed in detail. The reader might strike out the activities listed in Table 1 as they are identified by their corresponding arrows in the

FIGURE 2 - TENTATIVE NETWORK FOR IMPLEMENTATION OF SUGAR INDUSTRY PROJECT IN S.E. NANUM



network, in the following discussion.

Second step calls for judgement, permits flexibility.

The end desired goal in implementing the Sugar Industry Project of Starting-up and producing sugar for the first time, identified as activity W in Table 1, is represented by the arrow whose beginning and end events are numbered 15 and 16 respectively. Hence, activity W may also be uniquely defined in the network as activity (15-16). The numbering of the events in Figure 2 will be used in referring to activities in the network for purposes of the present discussion. In fact, the detailed numbering process can only occur in the next step and will be explained accordingly. Before the sugar-production activity (15-16) can commence, installation of the factory machinery and equipment, provision of power and water supplies, and testing out, identified as activity M in Table 1, must be completed. Therefore arrow (12-15) in Figure 2 shows activity M clearly preceding activity 15-16. Sugar-production also requires the harvest, transport and steady supply of cane sugar from the sugar-cane plantation to the factory, identified as activity V in Table 1, as well as transport and storage of other auxiliaries such as fuel oil, processing chemicals, and packaging materials, identified as activity Ø in Table 1. However, the sugar-production activity (15-16) can proceed as long as adequate supplies of sugar-cane and factory auxiliaries are available on time. Therefore, both activities V and Ø can be performed concurrently with activity (15-16), and have been represented by arrows (7-16) and (14-16) respectively, in Figure 2. Sugar-production, activity (15-16), also

requires the skills of several key personnel, who must be suitably housed and provided with community development facilities near the factory site, identified as activity N in Table 1. The latter activity is represented by arrow (8-15) in Figure 2. Activity (8-15) need not be completed for sugar-production to proceed. At least the permanent housing of key personnel and their community facilities may be extended until event 16 is reached. However, the socio-psychological factors involved in motivating key personnel to move into the new region are assumed to be sufficiently important as to require community facilities to be completed before activity (15-16) commences. Each of the three activities under discussion, namely (7-16), (14-16), (8-15), might be subdivided into more than one activity if desired. They have been aggregated as shown for the present illustrative purposes in order to simplify the example, and since they would each probably fall under the authority of different supervisors at the present level of responsibility in the actual implementation process anyway. The flexibility permissible in planning the implementation of activities (7-16), (14-16) and (8-15) become quite evident at this point, emphasizing the need for experienced judgement and collaboration on the part of the several diverse skilled persons involved in the process of planning and programming for implementation.

Second step proceeds using dummy activities.

Before the machinery can be installed, the factory building must be constructed, as identified by activity L in Table 1. Obviously the factory machinery and equipment must also be transported to the sugar-

factory site, as must also the cane-harvesting and cane-transporting equipment. These activities are identified as activities P and Q respectively, in Table 1. Accordingly, activity L is shown as arrow (5-12), and activities P and Q by arrows (9-12) and (9-14) respectively. Before any of the foregoing transportation or construction activities can be performed the new road from Akara to Nanum must be built, as identified by activity K in Table 1. Hence, activity K is represented by arrow (3-5) in Figure 2. However, event 5 also constrains the transportation activities of (7-16), (9-12) and (9-14), as well as the construction and other activities of (8-15). Hence dummy activities, represented by the dotted arrows (5-7), (5-8) and (5-9), are shown constraining the activities succeeding events 7, 8 and 9 respectively. The special property of the dummy activity of zero duration, requiring that the road-construction activity (3-5) must precede the transportation activities (9-12) and (9-14), as well as the construction activity (5-12) is clearly seen here. However, the activity (2-9) of procuring the factory machinery and equipment abroad, importing and shipping it to Nanum, identified as activity H in Table 1, constrains only activities (9-12) and (9-14), but does not constrain activity (5-12). Similarly, activity (2-7), the procurement of factory auxiliaries, identified as activity G in Table 1, and activity (1-8), the selection and training of key personnel, identified as activity E in Table 1, constrain activities (7-16) and (8-15) respectively, but do not constrain activity (5-12). Only activities (3-5) and (2-5) constrain all the activities that are constrained by the dummy activities, as well as activity (5-12).

Thus the logic and purpose in using dummy activities becomes clear. A similar situation arises at event 6, requiring the use of dummy activities. The activity (6-13) of clearing the land, building irrigation canals, reservoirs etc., while preparing for cultivation, identified as activity R in Table 1, must obviously precede the activity (13-14) of irrigating and fertilizing the land to cultivate sugar-cane, identified as activity U in Table 1. Also the activities (10-13) of providing self-help facilities to encourage housing and community development for worker families at suitable centers, identified as activity T in Table 1, and the activity (11-13) of transporting plantation auxiliaries to appropriate centers for storage, identified as activity S in Table 1, can proceed concurrently with activity (6-13), but must necessarily precede activity (13-14). However, before any of these concurrent activities can proceed, the activity (4-6) of constructing secondary roads at the sugar plantation, identified as activity J in Table 1, must be completed. Therefore event 6 must be reached before activities (10-13) and (11-13) can commence. Also the activity (1-10) of selecting, educating and transporting the plantation workers and families, identified as activity F in Table 1, constrains only activity (10-13); and activity (2-11) of procuring plantation auxiliaries like fertilizer, agricultural lime and pesticides etc., identified as activity I in Table 1, constrains only activity (11-13). Hence, dummy activities (6-10) and (6-11) are used to indicate the constraints that activity (4-6) imposes on activities (10-13) and (11-13) respectively. At this point the need to finalize all the various detail plans pertaining to roads, factory buildings, housing, community facilities, self-help

projects, acquiring of land, and awarding of contracts, before any of the activities described so far can be implemented systemmatically and successfully. becomes obvious. These activities are identified as B, C, and D in Table 1, and are shown as activities (2-3), (2-5) and (1-4) respectively in Figure 2. Finally, the approval of budgets that would initiate appropriate action on the basis of departmental estimates, consultant's reports and feasibility studies etc., as recommended by the Economic Planning Commission for Nabropat, identified as activity A in Table 1, must precede all of the foregoing activities. Figure 2 shows this first activity (1-2) occuring concurrently with activities (1-4), (1-8) and (1-10), thus completing the Tentative Network for Implementation of the Sugar Industry Project. Here again the need for experienced judgement, close collaboration and early consultation with the diverse departmental chiefs responsible for the implementation process, becomes readily evident.

<u>Third step systemmatically numbers events in network</u>.

The numbering of the events in the network proceeds forward from the logical beginning, or "Start", of the completed network to its final single end event, or "End", which signifies completion of the project. The numbering of the events may be done at random. However, an ordered numbering system provides the valuable advantage of avoiding logical inconsistencies, such as arrows in loops, or vicious circles, especially in larger networks where such logical inconsistencies cannot be readily detected visually. An ordered numbering system permits illogical inconsistencies to be detected in the tabulation of step

five for determining the critical path, even if visual checks for inconsistencies fail, while making manual computation easier as well. Also, when electronic computers are used in processing the data for larger networks, considerable savings in computer time can result if an ordering numbering system is used. The ordered numbering system requires that the number assigned to the commencement events for any activity, which includes all dummies, always exceed the number assigned to the end-event for the same activity, no matter how many activities commence and terminate on any of the events. A few simple basic rules must be followed in numbering a network to provide the desired ordered numbering system: (1) Assign a number to the "initial-event" for the network. The "initial event" is identified as that from which arrows only emerge, but into which arrows do not enter; (2) imagine that all the arrows emerging from the numbered "initial event" have been deleted together with its preceeding events. One or more new "initial events" will now exist as a result; (3) assign different numbers to all the new "initial events" in any convenient order, but with numerically increasing values greater than those already used; (4) imagine that all the arrows emerging from the newly numbered events, taken in numerically increasing order, have been deleted as in rule (2), and repeat rules (3) and (4) successively until the "final event" is numbered. The "final event" would have no arrows emerging from it. The application of these four basic rules to the tentative network of Figure 2, has resulted in the ordered numbering system shown. The reader should check that the four basic rules have not been violated.

TABLE 2

FOURTH STEP IN IMPLEMENTATION-PLANNING PROCESS

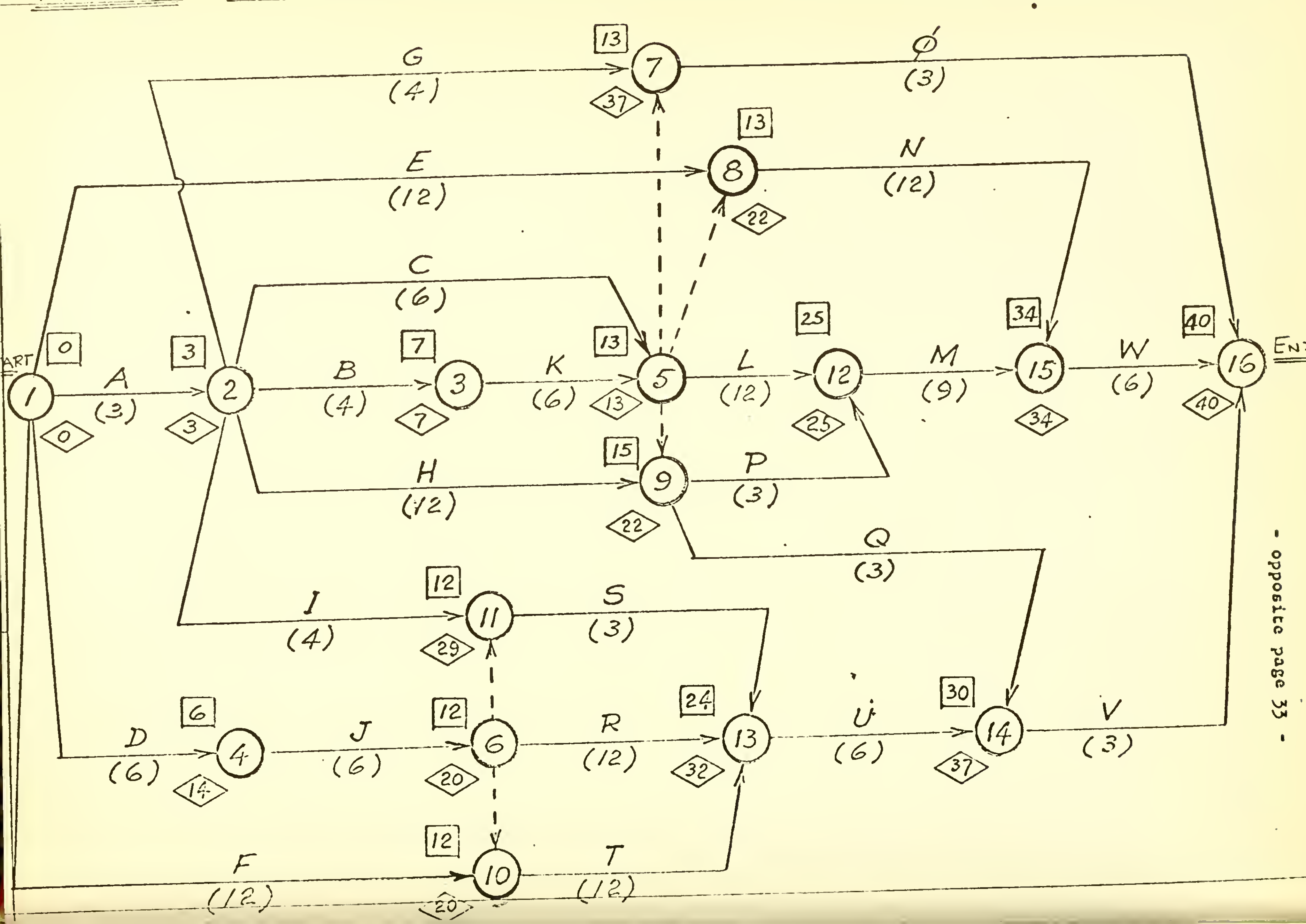
List of Activity Durations and Direct Costs

Activity Identity	Normal Duration Months	Normal Duration Cost $	Rapid Duration Months	Rapid Duration Cost $	Duration-Reduction Range Months	Duration-Reduction Rate $/Month
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A	3	3,000	2	6,000	1	3,000
B	4	4,000	3	8,000	1	4,000
C	6	6,000	4	10,000	2	2,000
D	6	10,000	4	15,000	2	2,500
E	12	120,000	8	240,000	4	3,000
F	12	300,000	8	500,000	4	45,000
G	4	10,000				
H	12	500,000	9	620,000	3	40,000
I	4	10,000				
J	6	100,000	4	150,000	2	25,000
K	6	200,000	4	300,000	2	50,000
L	12	1,000,000	8	1,170,000	4	42,000
M	9	300,000	6	405,000	3	35,000
N	12	500,000	8	580,000	4	20,000
O	3	5,000				
P	3	50,000	2	98,000	1	48,000
Q	3	20,000	2	30,000	1	10,000
R	12	300,000	10	375,000	2	37,500
S	3	4,000				
T	12	200,000	9	290,000	3	30,000
U	6	100,000	4	155,000	2	27,500
V	3	40,000				
W	6	90,000	5	65,000	1	15,000
		Total = 3,872,000		Total = 5,017,000		

Fourth step assigns activity-durations and costs.

In the fourth step, durations for performing each activity at the normal pace of work, as well as durations for performing each activity at the fastest possible, or rapid, pace of work, and the costs corresponding to these two durations are estimated. Such estimation calls for exercising the best available professional judgements in order to evolve a realistically integrated and comprehensive plan for implementation. The reasons for such realism are obvious and hardly call for further discussion. Obviously such realistic estimates must be provided as far as possible by the supervisor, who would be responsible for executing the particular activity and held accountable if his performance does not match his estimates. Table 2 shows the estimates used in this illustration. The durations and costs have been assigned to emphasize important features of network theory application in this practical illustration and to thereby achieve the demonstrative purposes of this example only. The estimates are not typical in any way and may not always appear too realistic. Obviously real-life estimates could vary very widely depending on the real-life circumstances and problems involved. Table 2 contains seven columns. Only the "Activity identity" is included in Column (1), omitting the description, for convenience. Columns (2) and (4) give normal and rapid durations respectively, in months. Columns (3) and (5) give the corresponding costs in dollars. Column (6) gives the difference between the normal and rapid durations, which is called the Range of Duration in months. Column (7) gives the difference in cost for rapid and normal duration, divided by the Range of Duration, in dollars/month.

FIGURE 3 - DETERMINATION OF CRITICAL PATHS IN TENTATIVE IMPLEMENTATION NETWORK



Some activities may have only a normal duration of execution. Table 2 provides the data for proceeding to the fifth step of determining the critical path, which will now be explained.

Fifth step determines Critical Path from earliest and latest event times.

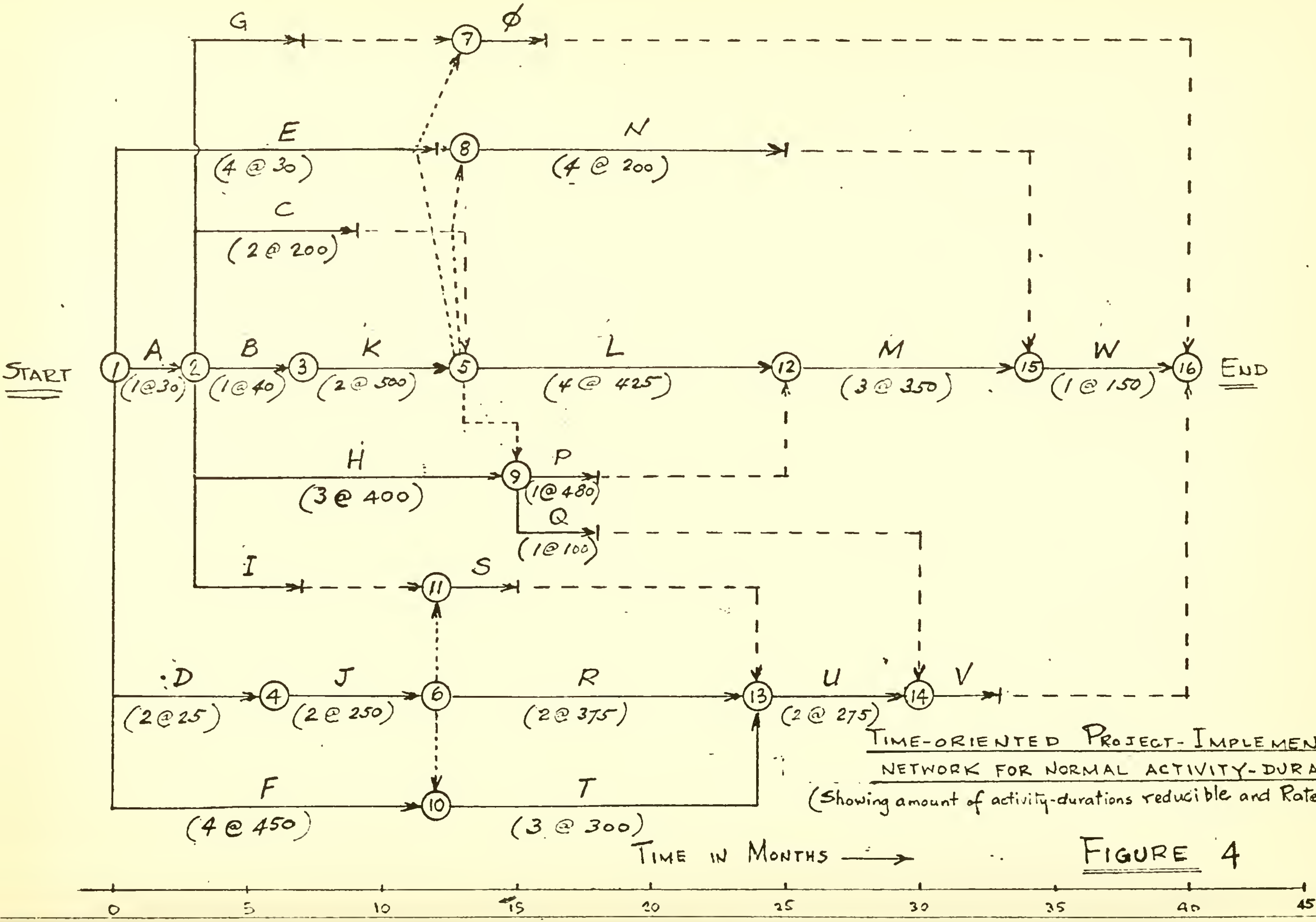
The Tentative Network of Figure 2 has been redrawn in Figure 3 omitting the description of each activity. Only the activity identifies of Table 1, in capital letters, and their normal durations, in parantheses, have been included in Figure 3. The length of the arrows is purely arbitrary, bearing no relation whatever to activity-durations. In any network certain activities will contribute directly to the overall duration of the project, and will therefore lie on the path of longest overall activity-duration in the network. This longest path is termed critical as well. Obviously at least one critical path must exist in a network. However, more than one critical path may exist in a network, depending on the durations of concurrent activities and their interdependencies. Paths that are not critical, but that could become critical if the durations of one or more activities increases, are called sub-critical paths. Sub-critical paths would obviously vary in degrees of criticality in proportion to the extent of the duration required to make them critical.

In order to analyze a network for critical paths the earliest and latest chronological times at which events may occur must be determined. These chronological times are referred to as the "earliest event times" and the "latest event times" for convenience, and must not be confused with activity-duration, which is merely the length of time

required to perform a given activity regardless of chronology. The earliest event times for all events in Figure 3 are determined first, commencing with the first event as zero chronological time and proceeding sequentially up to the last event.

The earliest event time of any event is determined by the following simple rules: (1) Add the activity-duration of each activity which ends on the event whose earliest event time is required, to the corresponding earliest event times of the commencement-event of each activity, and select the highest value obtained; (2) the process of rule (1) must proceed sequentially from the first event in the network to the last event, in the ordered sequence in which the events have been numbered; (3) the first event in the network must obviously be assigned a chronological, earliest event time before the process of rule (1) can commence. Similarly, the latest event times is determined by the following simple rules: (1) Subtract the activity-durations of each activity which commences on the event whose latest event time is required, from the corresponding latest event times of the end-event of each activity, and select the lowest value thus obtained; (2) the process of rule(1) must proceed sequentially from the last event in network to the first event, in reverse of the ordered sequence in which the events have been numbered; (3) the last event in the network must obviously be assigned a chronological latest event time before the process of rule (1) can commence. One distinct advantage of the ordered numbering system employed becomes evident in the application of the above rules. These rules have been applied to the network of Figure 3. The earliest event time so obtained for all

Critical Path: 1-2-3-5-12-15-16



TIME-ORIENTED PROJECT-IMPLEMENTATION NETWORK FOR NORMAL ACTIVITY-DURATIONS

(Showing amount of activity-durations reducible and Rates)

FIGURE 4

events are given in a little square box <u>above</u> each circled event number. Similarly, the latest event times are given in little diamond-shaped boxes <u>below</u> each circled event number. The reader might familiarize himself with the rules by checking the earliest and latest event times given in Figure 3. The critical path is identifiable by the events whose earliest and latest event times are equal in Figure 3, because the latest and earliest times for the last event were made identical; if not, the difference between the two times would similarly identify the critical path, or paths. This difference could well be negative if the "earliest event time" exceeds the "latest event time", indicating the need for appropriate action, which will be discussed in the next step.

<u>Fifth step - Critical Path and implications from time-oriented network</u>.

The Critical Path may as well be determined by different tabular methods which will not be discussed here. The graphical procedure of drawing a time-oriented network, based on the network of Figure 3, offers the greatest advantages. Not only does the time-oriented network point out the critical path, but all sub-critical paths and their several other implications as well. The time-orienting procedure and these implications will now be discussed.

Figure 4 shows the time-oriented Project-Implementation Network for Normal Activity-durations drawn against a horizontal time-scale of months. In this network the lengths of the full-lined arrows are drawn to scale representing activity-durations measured between the centres of the circles bearing the respective event numbers. The process of constructing the network must proceed sequentially from the lowest-numbered, or

"Start", to the highest-numbered, or "End", event in the network. The horizontal lines are evenly spaced for clarity and the vertical lines serve to retain continuity and identity with commencement-events, as the need arises. It is helpful, though not essential, to follow the same relative location of the activities in the time-oriented network of Figure 4, as in the basic network of Figure 3. Dummy activities are represented by dotted-lined arrows joining the respective events, as for dummies (5-7), (5-8), (5-9), (6-10) and (6-11). Since events 7, 8, and 9 are constrained by event 5 they cannot be shown to occur before event 5 occurs at month 13. However, they could obviously occur any time after that, as for event 9 which occurs at month 15, since successively preceeding activities A and H require 3 and 12 months respectively. On the other hand, activities G and E, which are shown to start immediately after event 2 occurs, are complete 6 and 1 month respectively, before event 5 occurs, as shown by the short vertical stubs after the arrows representing G and E. Thus respectively G and E are said to have <u>activity float times</u> of 6 and 1 months respectively, and are represented by the broken-lined arrows terminating on their respective end-events 7 and 8. Activity float therefore obviously indicates the extent to which the start of activities G and E may be altered without interferring with other activities or event-schedules in any way. Similarly activity C permits a 4 month float. The dotted-lined arrows representing dummies (5-7) and (5-8) are drawn slightly skewed for the sake of clarity only. Event 6 occurs at month 12 as required by activities D and J and therefore permits no float for activity F, but does permit a 5 month float for

activity I. The permissible float for activities Ø, N, P, Q, and V are readily seen as well, in the time-oriented network of Figure 4.

In some instances activity float may be more usefully transferred to events and regarded as <u>event slack</u>. For example, activities P and Q permit 7 and 13 months float, respectively. It is clear that event 9 could be permitted to occur a maximum of 7 months later than shown without upsetting project-completion, although activity H does not appear to permit any float, while still permitting activity Q a 6 month float. Therefore event 9 has a 7 month <u>slack</u>, which in effect exactly corresponds to the difference between the latest event times and earliest event times of Figure 3.

<u>Float</u> is associated <u>with activities</u>; and <u>slack with events</u>. Events that do not have any slack are clearly seen to lie on the critical path (1-2-3-5-12-15-16). Obviously any increase in duration of activities on this critical path would delay the project completion date correspondingly. If the latter date were fixed from other considerations, then all critical events would have negative slack, which would obviously have to be eliminated by speeding some activities up appropriately to meet the completion date. Where all the negative slack cannot be eliminated the realities of the situation and its implications to the overall programme will have to be courageously faced up to. At times, only some individual events might have fixed completion dates imposed on them due to their interdependence with other projects in the overall programme. Here again the elimination of any negative slack would be absolutely essential for a realistic implementation plan to evolve. Also during the course of project implementation the critical

path may shift to other previously sub-critical paths, or more than one critical path might appear. It is seen that the diverse implications of critical and sub-critical paths to project implementation can be analyzed more readily, and dealt with more effectively, by using the time-oriented network. Further implications of critical and sub-critical paths to time, cost and resources-allocations will emerge in the following steps.

Sixth steps contracts Network for minimum cost increase.

The time-oriented network of Figure 4 is now systemmatically contracted to give the shortest possible overall duration for the least possible increase in direct costs. Such a procedure provides some valuable, if not indispensable, insights into variation of total project costs with overall project duration, and therefore of overall duration to project implementation. Table 2 shows total direct costs of $3,872,000 under column (3) for normal activity-durations. If all activities are performed at their rapid durations, the total direct costs rise to $5,017,000, as seen under column (5). The futile wastefulness of performing all activities at their fastest pace in order to meet deadlines becomes obvious from a brief examination of the time-oriented network of Figure 4. However, instances of just such "crash action" to speed up project completion are not uncommon in project implementation, even in the developed countries. While some more obvious economies can be readily effected by examining Figure 4 closely, not all economies, usually the most substantial, can be exploited to the full by mere examination alone.

The following simple rules permit all possible economies to be

systemmatically and fully exploited by using both the network of Figure 4, as well as the list of Activity Durations and Direct Costs for normal and rapid durations of Table 2: (1) from Table 2, enter the "Range of Duration-Reduction", column (6), and the corresponding "Duration-Reduction Rate", column (7), against each activity in the time-oriented network for normal durations, of Figure 4; (2) progressing systemmatically from the lowest to the highest Rates for "Reduction in Activity-Durations", decrease the duration of all activities on the critical path as much as possible, examining the separate effects of each individual reduction in activity-duration on all other activities and events, until one or more sub-critical paths becomes critical as well. Reduction in the duration of activities on the critical path reduces the Overall Project Duration by the corresponding amount; (3) continue the process of rule (2) until no further reduction is possible, remembering that each time an additional critical path appears in the network, any further reduction in overall project duration may possibly involve the corresponding reduction in activity-duration of at least one activity on each such additional critical path.

Sixth step in detail.

The application of foregoing rules to the network of Figure 4 has been tabulated in Table 3 and produced the new, fully-contracted Project-Network of Figure 5, both of which will be discussed now. Column (1) in Table 3 identifies activities both by letter and by event numbers. Line 1 merely gives the total direct cost of the project with all activities at normal duration in column (5) and the corresponding overall project duration in column (6). From Figure 4, activity A (1-2) is seen

TABLE 3

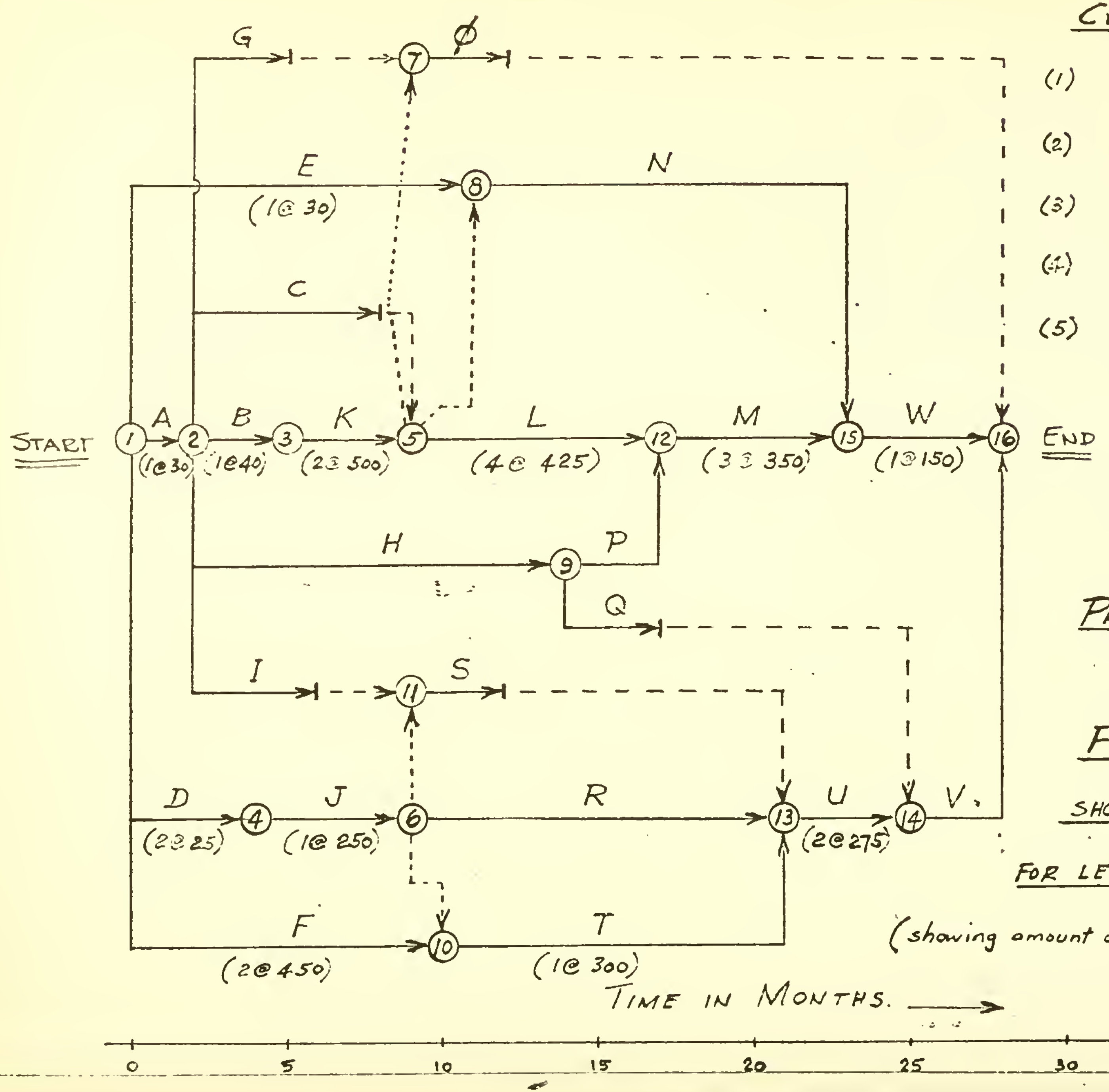
SIXTH STEP IN IMPLEMENTATION-PLANNING PROCESS

Contraction of Network to Shortest Duration at Least Possible Direct Cost Increase

	Activity Identity	Reduction in Activity-Durations			Total Direct Cost	Overall Project Duration
		Rate for	Amount of	Cost of		
		100 $/Month	Months	100 $	100 $	Months
	(1)	(2)	(3)	(4)	(5)	(6)
1.	All jobs at normal duration				38,720	40
2.	A(1-2)	30	1	30	38,750	39
3.	B(2-3)	40	1	40	38,790	38
4.	W(15-16)	150	1	150	38,940	37
5.	M(12-15)	350	3	1,050	39,990	34
6.	L(5-12)	425	1	425	40,415	33
7.	L(5-12)	425	2	850		
	U(13-14)	275	2	550		
		Effective =	2	Total = 1,400	41,815	31
8.	L(5-12)	425	1	425		
	D(1-4)	25	1	25		
	T(10-13)	300	1	300		
		Effective =	1	Total = 750	42,565	30
9.	K(3-5)	500	1	500		
	D(1-4)	25	1	25		
	T(10-13)	300	1	300		
		Effective =	1	Total = 825	43,390	29
10.	K(3-5)	500	1	500		
	J(4-6)	250	1	250		
	T(10-13)	300	1	300		
	E(1-8)	30	1	30		
		Effective =	1	Total = 1,080	44,470	28

to have the lowest Rate, for a reduction in activity-duration of 1 month. Line 2 shows this rate of $3,000/month in column (2) and the 1 month reduction in duration of the activity A (1-2) in column (3). The Cost of the 1 month reduction of $3,000 is entered in column (4), increasing the Total Direct Cost of Project by $3,000 to $3,875,000, in column (5). The Overall Project Duration thus reduces to 39 months, which is shown in column (6). While this first 1 month reduction shortens the critical path, it is seen to affect the sub-critical paths (5-8-15) and (1-4-6-13-14-16) differently, and lengthen the other paths that commence with event 2. Hence, the effects of reducing the duration of activity (1-2) must be examined closely, although no new critical paths yet appear, before proceeding with further reductions. The 1 month reduction may be regarded as eliminating the 1 month float either in activity (1-8) or as shortening the path (5-8-15) by 1 month, which would reduce slack for event 8 by 1 month. The sub-critical path (1-4-6-13-14-16) is necessarily brought 1 month nearer to becoming critical, while the floats for activities (2-11) and (9-14) both increase by 1 month. Lines 3, 4, 5 and 6 in Table 3 show the reductions in activity-durations progressing systemmatically from the Rate of $40/month for activity B(2-3), to $425/month for activity L(5-12), in accordance with the foregoing rule (2). At line 6 the Overall Project Duration reduces to 33 months, when Figure 4 shows that the path (1-4-6-13-14-16) also becomes critical. Thus, in accordance with rule (3), further network-contraction requires reduction of activity-duration in the new critical path as well. In this case, except for reduction in activity U, such further contraction requires that both the paths (1-4-6-13)

and (1-10-13) must be appropriately reduced in duration simultaneously. Activity L, which was last reduced in Line 6, still permits a further reduction of 3 months. Activity U permits a reduction of 2 months at the lowest cost increase of $27,500 on the new critical path. Therefore, line 7 shows the reduction of 2 months in each of the activities L and U at the Rate of $70,000/month, producing an overall project duration reduction of 2 months at total cost increase of $140,000. Activity L may be further reduced by 1 month, but now requires that both lowest-rate activities D and T on the new, doubtly critical path be reduced simultaneously to give an effective 1 month reduction in Overall Project Duration, as shown by line 8 in table 3. The fact must be emphasized that even if activity F involved a lower rate than activity T, the former's selection is subject to the constraint that event 10 can never occur before event 6. At this point the path (5-8-15) also becomes critical. Only the duration of activity K remains to be reduced at this point. Activity D permits a 1 month reduction, while activity T permits a 2 month reduction. Line 9 on Table 3 therefore shows activities K, D and T each reduced in duration by 1 month at a total cost increase of $82,500. This 1 month reduction has now made activity E, which permitted a 1 month float, critical as well. The final 1 month duration-reduction now involves activities K, J, T and E at a total increase of $108,000, as shown in line 10, Table 3. The final Total Direct Cost for implementing the Project in the shortest possible overall duration of 28 months at the least possible Direct Cost increase of $598,000, works out to $4,470,000. This least possible total contrasts with that of $5,017,000 if all activities were speeded up indiscriminately.



Critical Paths:

(1) 1 - 2 - 3 - 5 - 12 - 15 - 16.

(2) 1 - 8 - 15.

(3) 1 - 4 - 6 - 13 - 14 - 16.

(4) 1 - 10 - 13 - 14 - 16.

(5) 2 - 9 - 12.

FIGURE 5

PROJECT IMPLEMENTATION NETWORK.

FULLY CONTRACTED TO SHORTEST OVERALL DURATION FOR LEAST POSSIBLE DIRECT COST INCREASE

(showing amount of activity-durations contracted and corresponding rates.)

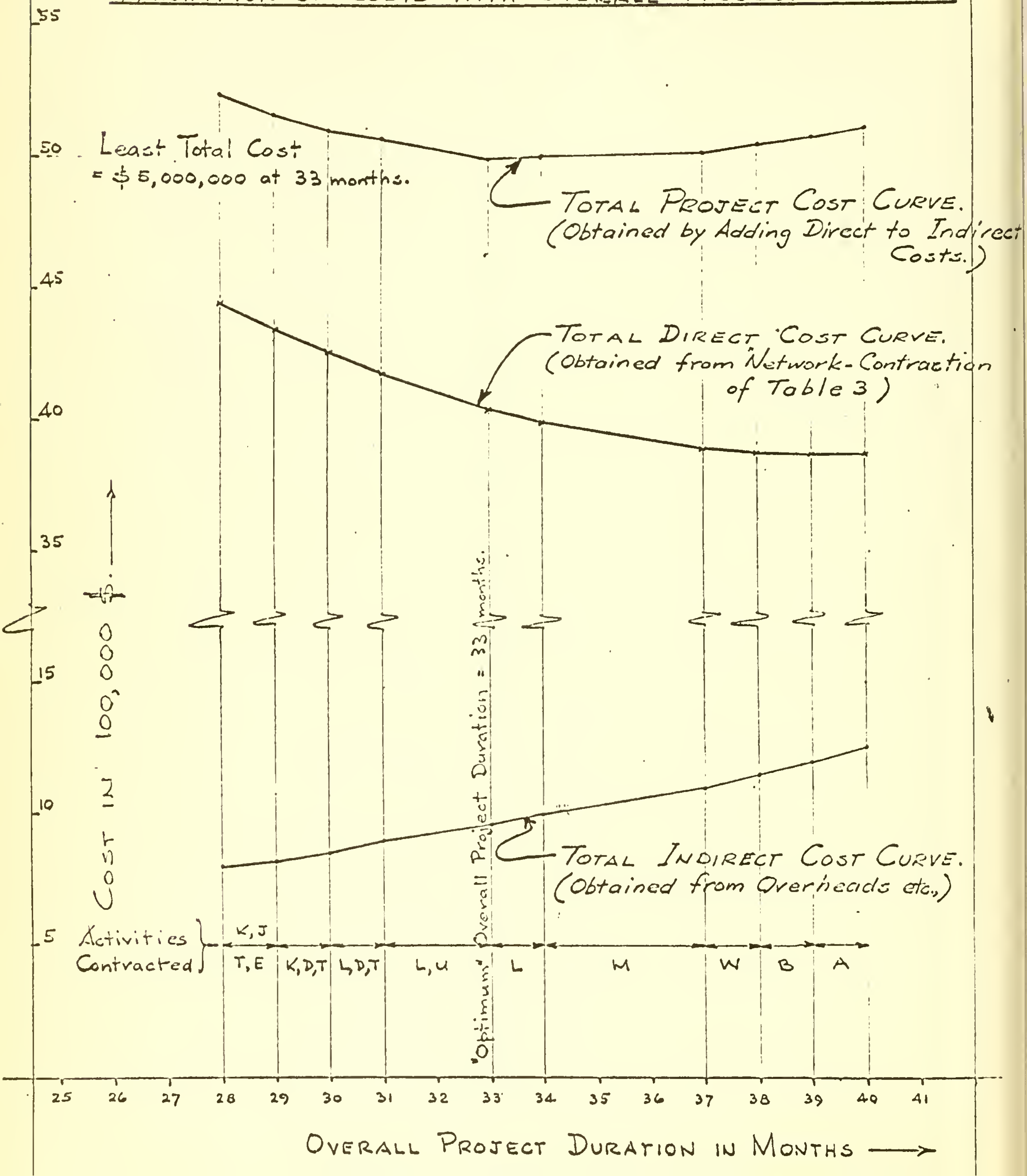
The resulting fully contracted network has been drawn in Figure 5, indicating the extent of the duration-reductions of each activity in parantheses. This network of Figure 5 will be used later for continuing the implementation planning and programming process. The use of Table 3 for purposes of further cost analysis will now be discussed.

Seventh step determines minimum total project costs.

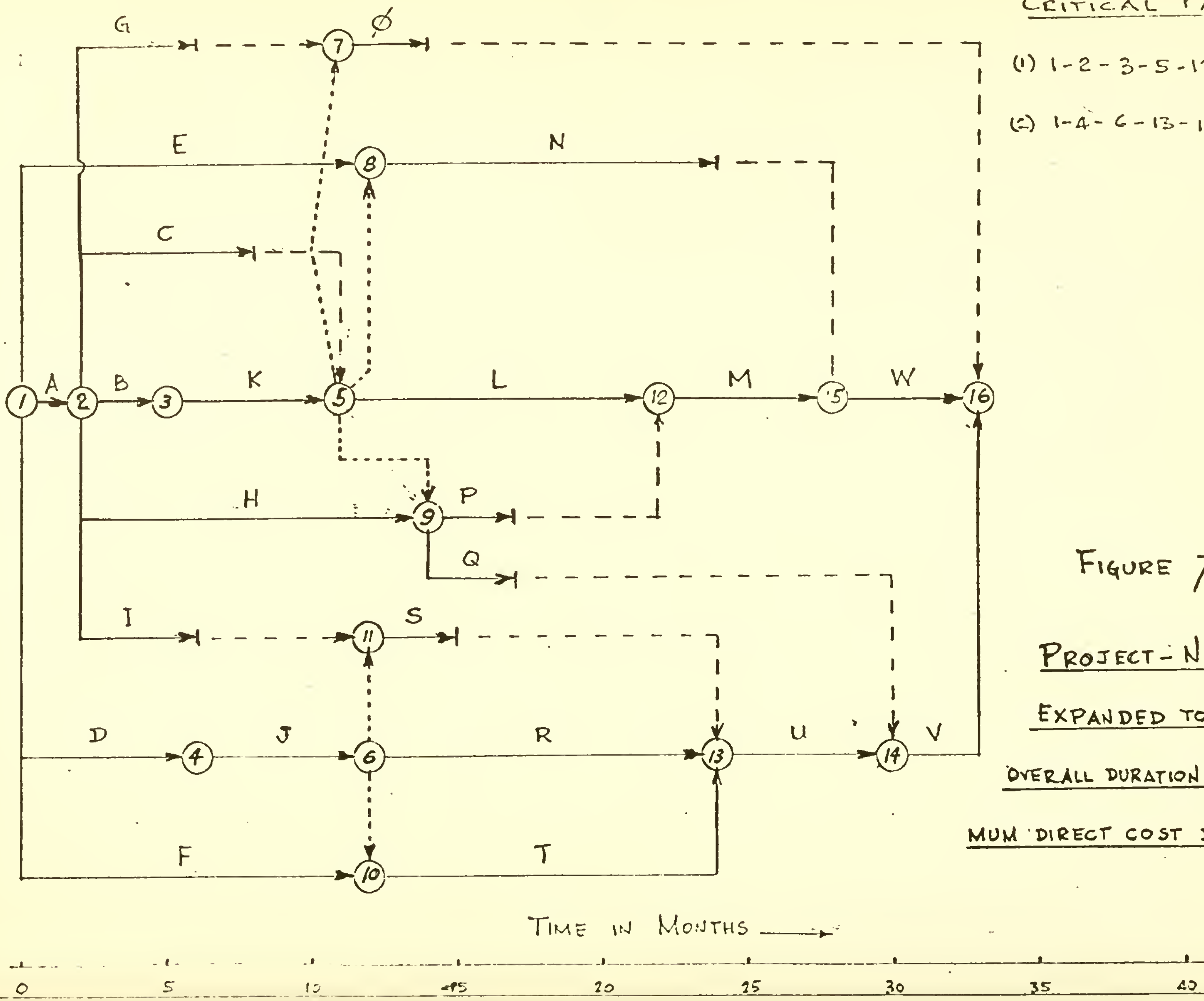
Total Project Costs equals Total Direct Costs plus Total Indirect Costs incurred in project implementation. In the seventh step the direct cost analysis of Table 3 permits further analysis of Total Project Costs by the inclusion of all costs that are not classified as direct costs. The latter could include all manner of administrative overheads, supervision costs, governmental expenses, interest payments on loans and virtually any other type of non-direct expense on the Project. In some cases penalty costs of various kinds for inability to meet schedules may be involved as well. Different categories of indirect costs could be aggregated and treated separately. However, for the present purposes of this paper, indirect costs would imply all possible non-direct costs, since the basic principle for analysis remains the same whether one or more distinct, contributory categories of costs are considered separately. Figure 6 shows the variation of Total Direct Costs from Table 3, column (5), plotted against the Overall Project Duration under column (6). The varying but distinct decrease in Total Direct Costs as overall duration increases, is clearly seen. Total Indirect Costs, on the other hand, generally tend to increase as overall duration increases. The rate and amount of the increase would obviously vary with the particular activity

FIGURE 6.

VARIATION OF COSTS WITH OVERALL PROJECT DURATION.



whose duration-increase is responsible for the overall increase. In very rare instances certain specific types of indirect costs may tend to decrease in duration. Whatever the detailed indirect cost breakdown, the Total Indirect Cost variation could be determined even approximately, and will generally display an increasing trend. For present purposes the Total Indirect Project Cost Curve shown in Figure 6 is assumed. The activities that were progressively contracted and their corresponding duration-reductions are also indicated in Figure 6. Different variations in indirect costs with time are assumed for each activity in keeping with the type of activity. The individual amounts of the cost-increases for each duration-increase are seen from the Total Indirect Project Cost Curve. The reader might compare relative Indirect Cost variation by reference to the labelled Tentative Network of Figure 2. Obviously, the more accurate the curves the more accurate the cost analysis becomes. The Total Project Cost Curve is obtained by merely adding the Total Direct to the Total Indirect Costs. The resulting curve of Figure 6 shows that a minimum Total Project Cost of $5,000,000 becomes possible for an Overall Project Duration of around 33 months by contracting activities A, B, W, M fully, and activity L by only 1 month, as shown by lines 1 to 6 in Table 3. The Overall Duration of 33 months corresponding to the minimum Total Project Cost is called the "Optimum" Overall Project Duration for convenience. Obviously as new situations arise and improved evaluations of all the diverse factors involved in the Implementation Planning and Programming Process are arrived at, the "optimum" duration could vary accordingly and be re-evaluated as well. The foregoing



CRITICAL PATHS:

(1) 1-2-3-5-12-15-16.

(2) 1-4-6-13-14-16.

FIGURE 7

PROJECT-NETWORK

EXPANDED TO "OPTIMUM" OVERALL DURATION FOR MAXIMUM DIRECT COST DECREASE

"optimum" cost-duration analysis will now be made use of in the next step, to obtain the first Working Network for Project Implementation.

Eighth step expands Network to "Optimum" Duration.

In the eighth step, the fully-contracted Project Network of Figure 5 is expanded to the "optimum" Overall Project Duration of 33 months so as to correspond to the minimum Total Project Cost of $5,000,000, giving the greatest possible Total Direct Cost reduction, and therefore the corresponding least possible increase in Total Direct Costs as well. The process of network-expansion to obtain maximum Direct Cost decrease, is carried out in exact reverse of the process of network-contraction to obtain minimum Direct Cost increase, discussed in the sixth step. The extent of the expansion possible in each activity-duration obviously corresponds to the amounts of the contractions made in the sixth step. These amounts and their corresponding rates are inserted under each activity in Figure 5. However, the actual process of network-expansion does not have to be repeated as in the sixth step. It is easy to see that the greatest possible Direct Cost reduction is obtained by starting the network-expansion process with line 10 in Table 3, and at an Overall Project Duration of 28 months, proceeding backwards to line 6, when Overall Project Duration equals 33 months. Figure 7 shows the first Working Project Implementation Network, expanded to the "optimum" overall duration for maximum Direct Cost decrease, and therefore gives the minimum Total Project Cost as well.

Ninth step - resource-allocation improvement.

So far only dollar costs were involved in considering the implications of critical path networks in the implementation-planning process.

More money was assumed to be the only item necessary to speed up the successful performance of activities. Less money was assumed to slow down this activity-performance rate. For each activity, even linear variation of cost with duration was assumed. However, in fact money is only the means used to acquire the services of men who require all kinds of materials and machines to perform the various activities. Not only will variation of cost with duration be non-linear for most activities, but the men, machines, materials and any other resources, would be in limited supply as well. Therefore, considering the mere allocation of money to an activity would not alone produce the soundest implementation plan. In fact, failure to recognize the effects of limited resources in the implementation planning and programming process would result in serious practical problems as implementation of the plan progresses.

The "implementation gap", as defined at the very outset in this paper, stems in many ways from the emphasis placed on money-allocations in the financing of economic development and the latter's planning and programming. Often elaborate and sometimes bewildering mathematical models and techniques are used to "optimize" these money-allocations. Little evidence seems available to the use of even simple models and techniques in the allocation of limited resources in those same development planning and programming processes. While the processes of planning, programming for implementation must necessarily begin with money-allocations, the same processes can only be of any real practical value to the extent that resource-allocations complete those processes. The longer that such resource-allocations are postponed in the implementation planning and

programming process, the greater the jeopardy in which the successful implementation of the plan is placed. Use of critical path networks presents the first step towards minimizing that jeopardy even if only cost is analyzed and minimized as described in the foregoing eight steps in using critical path networks.

A theory for resource-allocations in critical path network application, that would be of any practical value in the development process, has yet to be expounded. The expanding body of knowledge within which theories for resource-allocation improvement falls, is called Operations Research and cannot be discussed here at all. However, the networks set up and analyzed so far have substantial practical value in enhancing the planner's judgement and improving his resource-allocation processes, no matter how efficient those processes might presently seem without using any networks. Here, the ninth step merely illustrates some basic ideas and principles of application for improving resource-allocations using critical path networks. The networks of Figure 2 and 4 will be used to illustrate these basic ideas.

Ninth step illustrates resource-allocation improvement.

Skilled managerial and supervisory personnel of all kinds are perhaps the most scarce of all resources in the developing countries. Therefore the present illustration will be confined to discussing the allocation of this scarce personnel resource only. However, the basic idea and principles of application remain the same for almost any type of resource. The network of Figure 2 shows that at any given instant during the implementation of the Project several activities could be in the

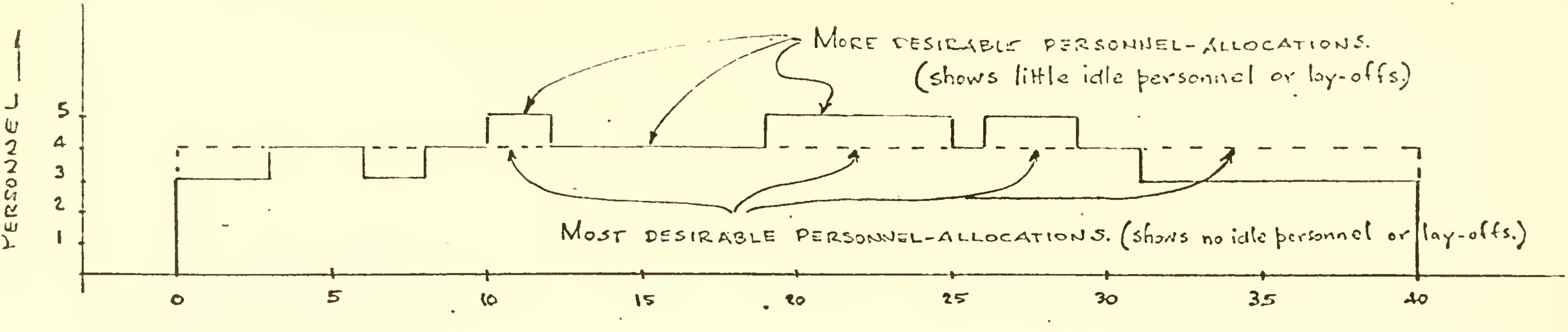


FIGURE 9B. IMPROVED SUPERVISORY-PERSONNEL REQUIREMENTS OF NETWORK IN FIGURE 8.

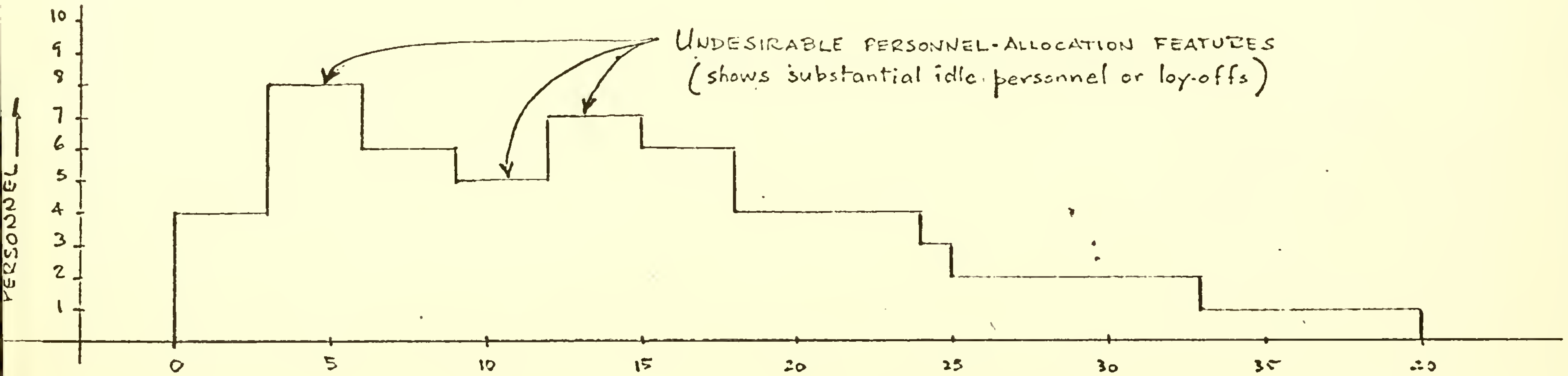


FIGURE 9A. SUPERVISORY-PERSONNEL REQUIREMENTS OF NETWORK IN FIGURE 4.

process of execution. For present purposes the assumption is made that each distinct activity is executed under the supervision of one skilled manager. In fact, one skilled manager may be responsible for more than one activity, depending of course on the nature and relative locations of similar activities. The time-oriented network of Figure 4 permits all the activities that are occuring concurrently at any given instant, or period of time, to be determined by merely counting the total number of horizontal solid lines above that period on the horizontal scale. The number of such lines would indicate the number of skilled personnel required to supervise project-implementation at that time, on the basis of one supervisor per activity. Figure 9A shows the resulting distribution of supervisory-personnel for the network of Figure 4. The variable number of such personnel over the duration of the project is quite evident as well. A maximum of 8 supervisors is required around month 5 with the number reducing to 5 around month 10, increasing to 7 shortly thereafter and reducing progressively to one at month 40. Such an allocation of hard-to-find skilled personnel, most of whom are usefully employed for only a few months at a time, is clearly undesirable and wasteful, even if they are available for such short periods of activity. The more desirable allocation of such personnel obviously calls for the steady employment of a smaller number over the whole life of the project, if possible.

A more uniform distribution of supervisory personnel becomes possible through re-scheduling those activities in the network of Figure 4 so as to make the best use of the activity-float and event-slack that the implementation network shows is available. Figure 8 shows one such

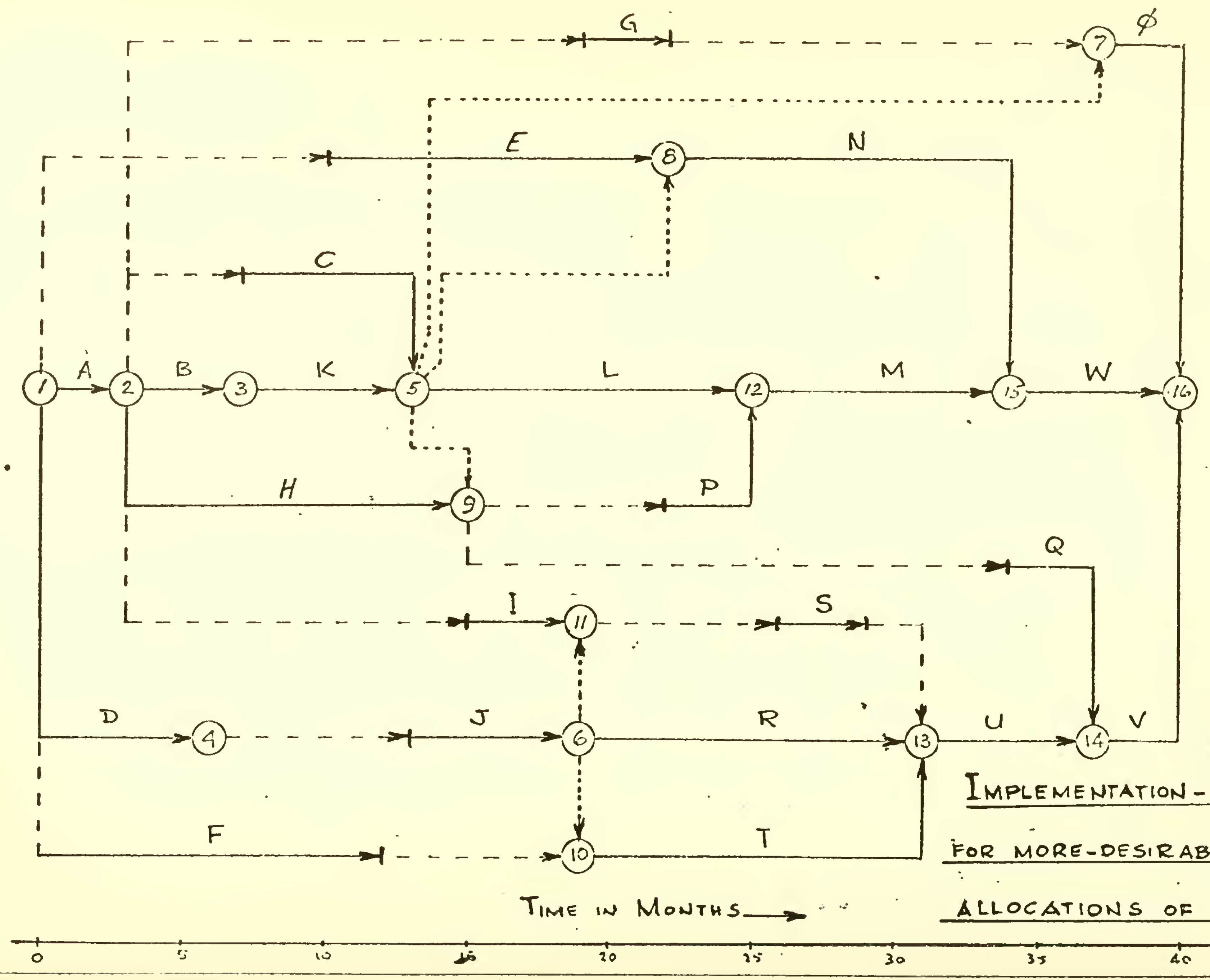


FIGURE 8.

IMPLEMENTATION - NETWORK

FOR MORE-DESIRABLE PERSONNE

ALLOCATIONS OF FIGURE 9B

rearrangement of activities. Here similar activities like finalizing of detailed plans, procurement of various items, construction of roads, selection and training of personnel, construction of housing and buildings, transport of the different items, etc., have been so arranged that they do not all occur at the same time, as far as possible. Such a policy permits one single skilled supervisor to manage similar activities, whereas earlier more than one was involved for a short time, requiring idle-time or termination of services at others. The new allocation, or assignment, of supervisors possible is seen in Figure 9B, where a maximum number of only 5 supervisors is required, while 3 are required all through the project. The nature of some activities is such that they may not all call for continuous performance and in fact may even require breaking up into two or more different periods of execution. Thus the supervisory-personnel requirement could probably even be reduced to 4 persons assigned permanently for the entire duration of the project, making the best use of this very scarce resource in the developing countries. Obviously, all supervisory personnel would not be qualified to handle any type of activity in a project of great activity-diversity, thus imposing distinct limitations on the scope of the process just described.

However, the desirability of, and possible criteria for, designing on-the-job training programs for developing potentially versatile supervisory personnel also becomes clear at the same time. The applicability of the foregoing ideas to all other resources as well, in order of priority that corresponds to their scarcity, is readily recognizable.

The network of Figure 7, which was expanded to conform to the "optimum" duration and minimum Total Project Cost should in fact be used in the foregoing illustration. The network of Figure 4 was used instead, since the latter presented greater scope for presenting a more vivid illustration, made possible by the greater activity-float and event-slack the network incorporated, as compared to the network of Figure 7. Improving the allocation of all the various types of resources would in practice reduce to the allocation of the scarest resources first, which would progressively restrict the possibilities for improving allocations of the less scarce resources. However, the use of critical path networks provides a systemmatic basis on which priorities may be assigned to the available resources as well as for the revision of such priority-policies as the real-life situations demand. The final outcome of all the foregoing steps in the implementation planning and programming process would be the evolution of what might be considered a Master Plan Network for Project Implementation.

Tenth step provides for reviews, revisions and contingencies.

The Master Plan Network must not by any means be regarded as a rigid plan for implementation of the Project. On the contrary, the network permits the greatest possible flexibility for altering the implementation process as reviews, revisions and contingencies call for in the execution of the individual activities, but which changes are nevertheless consistent with the prime requirements of achieving the overall objectives and goals of the project as a whole. Unforeseen contingencies always arise in the real-world implementation of any plans

no matter how carefully made, calling for revision of plans as originally laid. For instance, unusual floods may delay the construction of secondary roads at the sugar planataion, activity J. The networks of Figure 8 show that a 7 month activity-float is permissible, but any further delay would affect activities R, U and V, besides extending overall project duration. The situation could be remedied by appropriately speeding up the activities on the critical paths to the extent that is desirable and possible. Or, where such remedial action is not possible the inevitability of a delayed project completion dates would have to be faced up to, with its implications to other projects and sectors. Again, the procurement or shipping of machinery and equipment abroad, activity H, may take longer than anticipated due to labor problems at home or abroad. A 7 month delay in completing activity H is tolerable without any serious consequences. However, if any circumstances delay the construction of the roads to the plant site, activity K, or the reaching of event 5 due to any other cause, the consequences to completion of the project on time are seen to be immediate. On the other hand, unexpected speedier execution of any activities on the critical path would permit valuable resources in personnel or machines to be diverted elsewhere. Similarly, the selection and training of skilled personnel, or of workers and their families, activities E and F, might turn out to be much more complicated than originally conceived of. Here again the consequences to project implementation as a whole could be evaluated as soon as the problem becomes evident and timely prevention or corrective action initiated, instead of when the problem actually becomes a reality when no corrective

action is usually possible. Of course a re-allocation of some resources would probably be called for in keeping with the changes proposed to deal with all new situations.

Some of the activities immediately involved in such re-allocations might be analyzed more closely for cost and resource variability exactly as done in the foregoing nine steps, using individual networks to break down and analyze each activity further. These further individual network analyses, for major activities on the critical path at least, would prove very valuable where very substantial costs are involved. Such a procedure also provides the bases for "trading-off" the needs of the individual activities against the needs of the overall project as a whole. The desirability of, and possibilities for, making adequate contingency provisions for strategic activities emerges with the use of the implementation networks. However, even if such contingencies have not been originally anticipated, the possibilities of timely and continuous revision of implementation processes can be readily appreciated. Apart from the anticipation of contingencies, serious problems could arise as a result of failure to satisfy some of the pre-requisities to the implementation stage listed earlier in this paper. While the implementation network cannot always assist in making up for the inability to satisfy such pre-requisities completely, the process of going through such comprehensive implementation planning and programming procedures will probably reveal serious omissions early enough to permit timely remedial action to be taken wherever possible, more often than not. In the extreme case it might at least indicate that the project should not be started until

such pre-requisities are fulfilled. It is hard to imagine how any implementation planning and programming process that does not use networks, or some other similar device, could cope with the diverse complications of dealing more effectively with the real-life contingencies that do arise in implementing complex developmental plans. No evidence is available at present, of any other devices, similar to critical path networks, being used in implementation of industrial development projects and programmes, in the developing countries.

Co-operation of other supervisory levels.

The implementation planning and programming process has been confined to the highest management, or supervisory, level in the illustration presented in this paper. The individual managers taking part in the planning process are assumed to take full responsibility for managing one or more activities and their successful, timely and efficient execution. Practical, day-to-day execution of any activity involves close, continuing collaboration and communication between the individual manager and his immediate sub-ordinates, or assistants, who take their instructions directly from him, and are directly responsible to him. As contended at the very outset in this paper, the whole process of implementation planning and programming at the highest levels using critical path network theory would be greatly enhanced, if the appreciation and co-operation of at least the next lower level of responsibility for actual project implementation were progressively encouraged. The best means for seeking this appreciation and co-operation would require that each manager plan the execution of his individual activity in

direct collaboration with his assistants, constructing a critical path network for activity-execution in the process. Such a process would call for aggregating sub-activities exactly as illustrated in the foregoing steps and assigning his supervisory staff accordingly. The latter would soon begin to appreciate the comparatively simple, but powerful, ideas involved in networking any complex activity, as the need for, and possibilities of, clear definition of interdependent sub-activities and their cost and resource implications emerge.

The process of network planning and programming for implementation will thus inevitably and logically proceed to the next lower level of responsibility in project implementation, with all its consequent advantages and economies. This process of network planning and programming at the next lower level of management will in all probability reveal important interdependencies that were overlooked at the higher level and will call for suitable revision of the Master Plan Network accordingly. Greater realism in time, cost and interface definition would result in the Master Plan itself and its analysis, from the more detailed network analyses at the lower levels. No necessity exists at all for incorporating all the individual lower level networks into the original Master Plan Network, as might at first be imagined. Of course the integrated networking process can only progress to the lower levels beneficially when the highest levels of project planning , programming, and implementing, appreciate and understand reasonably thoroughly, how critical path network theory can improve their own efficiency and productivity, both qualitatively and quantitatively, in managing programme and project implementation. When that point is

reached, sounder bases for the indigenous evolution of more efficient implementation systems and organizations, compatible with the urgent, ambitious, rapid-developmental aspirations of the developing countries would have been firmly established, hastening thereby the day when these aspirations would be realized.

Evaluation of network application in dynamic implementation.

The discussions of the foregoing ten steps for applying critical path network theory to project implementation planning and programming reveals the possibilities for satisfying several of the different requirements of successful, dynamic implementation systems listed earlier. A brief evaluation of these possibilities and some advantages could be reviewed now.

The very process of drawing up the list of all the aggregate activities that must be performed in implementing the project and constructing a realistic tentative implementation network, would open up channels of communication between the diverse departments and their experts that would qualitatively enhance present and future collaboration between the planners and those responsible for plan-implementation, or implementors, at the highest levels. These improved communications would enable the planners and the implementors to appreciate each others' points of view and problems, as well as enable the implementors themselves to understand each others' activities and difficulties more readily. Many practitioners of the networking-art claim that, even if the Tentative Network is not put to its fullest use after it has been drawn up, the very fact of having gone through the process of setting up the tentative network proves an indispensable means of providing all participants in the implementation

process a thoroughly comprehensive and invaluable picture of what integrated project implementation calls for.

In the process of network-preparation, clearer definition of responsibilities and bases for assigning priorities would be established that would be useful later in reviewing and modifying the network to suit changing circumstances as implementation progresses. Consequently, a deeper understanding of the diverse practical implications of the implementation process by all participants, would provide a greater sense of participation in the development process and a psychological boost to morale and overall teamwork as well, when these natural instincts are tactfully cultivated. The more realistic allocation of skilled supervisory personnel at the various levels would provide more realistic bases for setting up the administrative and organizational structures required for efficient project implementation, which might call for drastic re-organization of present structures. It is not uncommon to find developing countries attempting to set up advanced twentieth century industrial complexes and communities using administrative and organizational structures which were established to meet the simpler needs of the nineteenth century colonial era.

Network-planning for implementation would provide unmistakable recognition of the interdependent links between the various projects and activities in the different executive departments and sectors of the economy and their implications to overall programme and project implementation. Such clear definition of interdependencies would facilitate expediting the timely co-ordination of all interdependent activities wherever

required, permitting hasty improvisation and its consequent, expensive confusion, or blunders, to be averted. Unforeseen contingencies, natural disasters, or for that matter the discovery of serious blunders in planning, can be dealt with more rationally and effectively, due to the built-in flexibility that the Master Plan Network, and the ordered methodology that the networking process, provides.

Once responsibilities for activities have been clearly defined, manpower assigned and resources allocated to suit the deadline dates for completion of tasks, realistic criteria for evaluation of performance and overall progress have been established at the same time as well. Periodic progress reviews would therefore become more meaningful and practically useful than if no Master Network Plan were available. Such progress reviews would provide more valuable data for more realistic budgetory control and revision of annual bedgets based on actual performance. This last-mentioned feature bears special significance due to the fact that although industrial development plans are spread out over five or seven year periods, national budgets are estimated and approved only annually. Integrated network planning and programming for implementation of development plans on a national scale would therefore make for greater overall efficiency and economy in national affairs as well. In short, the application of critical path network theory to industrial project implementation provides sound basic principles on which not only the business of managing can be carried forward more efficiently and successfully, but also any sound program of systemmatic follow-up and supervision of industrial projects can be based. Several of the foregoing comments could be elaborated upon readily. From

considerations of time and space in pursuing the present purposes of this paper, such elaboration would have to be indulged in elsewhere.

Use of electronic computers in analyzing Critical Path Networks.

The example illustrated in this paper involves about 28 activities with 16 events and was comparatively simple to analyze, serving the demonstrative purposes of this paper quite effectively. In fact, implementation problems could incorporate many more activities and events, making analysis of the corresponding networks slower and more involved. The process of network analysis for critical paths, cost and resource allocations may all be executed almost automatically using appropriate computer programs. A variety of different computer programs are available for performing the critical path analysis described in the foregoing fifth step, to suit both the magnitude and complexity of the network as well as the type of computer that might be available. The same is true for the cost minimization procedures of steps six, seven and eight, although the range of programs may be somewhat more restrictive. In the allocation of resources of step nine, computer programs are being tried out, as are various theories and techniques in this field. Their efficiency for the purpose of implementation planning and programming cannot be readily evaluated just yet. Doubtless rapid progress is being made in this field as well.

It would be a great mistake to conclude that computers are indispensable in applying critical path network theory to implementation of development plans. In fact, computer programs should not be resorted to at all until the basic essentials of network analysis by manual means is thoroughly mastered and appreciated first. Such appreciation would

be greatly stimulated by the use of large display-boards in which the time-oriented networks could be set up. The boards could be designed to permit quick alterations to displays, as changing circumstances demand. However, no matter how large or complex the network the first steps of preparing the tentative implementation network can be carried through only by the collaboration of competent persons. No mechanical process can substitute for the indispensable skilled human effort called for. Often that process can become a very trying and frustrating experience at first. However, once this substantial capital investment of careful thinking required in the first four steps has been made, the process of setting up the time-oriented network to scale using large-sized ruled paper, as well as alterable display-boards, becomes comparatively easy. The process might be compared to that of preparing all the detailed engineering blue prints that any engineering project calls for. Nevertheless, the time-oriented network and its analysis turns out to be a comparatively simpler operation than that of producing all such detailed engineering blue prints, despite the greater relative importance of the integrated implementation process itself. The time-oriented Master Plan Implementation Network may well and truly be regarded as the <u>blue print</u> for <u>engineering the implementation of development plans</u>.

As appreciation of the value of implementation-networks grows through their application without the use of computer programs, depending of course on the initiative and ingenuity of the planners and implementors, the level of sophistication in the network-implementation-art will also advance. At that stage the greater possibilities for time, cost and

resource "optimization" will become increasingly evident. Efficiency and productivity bottlenecks will begin to be recognized where none were apparent before, as reporting systems are improved or set up, and information flows begin to get formalized and organized, which process will doubtless only evolve slowly. Such recognition of bottlenecks would stem from the quickening pace of more efficient implementation processes and systems, due precisely to the increasingly successful manual mastery of critical path network analysis and usage, without the help of computers. The use of a small computer could then be experimented with in order to eliminate possible bottlenecks. Where a computer is not available the basic data could be readily flown to a neighboring country where data-processing facilities do exist, since the time between periodic reviews would still conveniently permit the few weeks required to do so. At this stage, the evolution of dynamic implementation systems compatible with the urgent, rapid-developmental aspirations of the developing countries will become possible as well, as will the fact that the use of even a small computer could result in a major breakthrough in the implementation of development plans using critical path network theory.

HOW TO INTRODUCE CRITICAL PATH NETWORKS TO PROGRAMME-IMPLEMENTATION

Educate at highest level of planning and implementing.

The Critical Path Network just illustrated and discussed has been introduced over the past fifteen years or so, under a variety of names in the U.S.A. The Department of Defense has been gradually making the use of Networks mandatory on all their contracts, under the name of PERT (Program Evaluation and Review Technique), which is the most widely known. The National Aeronautics and Space Administration (NASA) seems to be adopting a similar policy. The construction industry uses Networks under the name of CPM (Critical Path Method). Those users who have taken the trouble of studying Critical Path Network Theory carefully and applying it intelligently, exhort its use and report substantial economies of cost and time, as well as a variety of benefits to their organizations. Those who have not understood the method completely, but have nevertheless been obliged to use it by their customers, waste substantial resources in doing so, and deprecate the method. The writer has had the good fortune to have worked closely with the latter category as well, and learned a great deal of how the network theory should not be used.

The principle reason why the theory is disparaged seems to be, that apart from a poor understanding of the comparatively simple principles of the theory, top management in the organization is not convinced that the theory has any appreciable merits; possesses neither the inclination nor the time to study it closely and prefers to carry on with their traditional methods anyway. Therefore the theory is used only when customers insisted,

with no incentive to, or effort by, middle management to understand the theory in depth. For these and other reasons, the writer is convinced that the Critical Path Network Method must first be found acceptable by both the highest echelons of planners and implementors in any developing country, in order to produce any worthwhile results.

Manual on Application of Critical Path Networks required.

Convincing responsible persons of the value of innovations, especially at the top levels, is a formidable task, and would require a carefully-designed program of education designed especially to reach them. A Manual propounding the theory and practice of the Application of Critical Path Network Theory to Plan Implementation, illustrated with concrete examples, would seem to constitute a first requirement of such a program of education. Of course the value of such a manual would be greatly enhanced if it could be prepared from practical experience gained in the process of actually applying the Network Approach in improving present implementation processes in a developing country. Such an attempt could assume the form of a pilot project or programme in that country.

To begin with, a development plan of the particular country could be studied closely and a tentative network prepared to suit the proposed plans. In all probability inadequacies in the information available in the plan for purposes of implementation planning and programming would become evident after some preliminary readings. However, the tentative network could be prepared on the basis of reasonable assumptions where necessary. Such a study would open the way to taking the next step of further collaboration with the planners and implementors within the country

itself. When the handbook is compiled on the basis of actual experience gained in the country, the way should be opened to convincing top planners and implementors of development plans, that the systems and processes they currently employ could be improved both upon quantitatively and qualitatively in achieving their planned objectives. The Manual would provide the basics which would enable all the developing countries' planning commissions to produce tentative implementation-networks with all their development plans, and thereby bring greater realism and dynamism to the implementation of their plans. While the highest levels of planning and implementation are being persuaded and convinced, the comparatively simple fundamentals of network theory could be taught at the lower levels, as well in technical schools and adult education programs. Such programs of education would progressively prepare all levels to co-operate and participate wholeheartedly in implementing the introduction of Critical Path Network Theory to Development Planning, Programming and Implementation in the most successful manner possible.

FURTHER RESEARCH IN DYNAMIC IMPLEMENTATION SYSTEMS AND PROCESSES

Interdependencies in all development plans.

The network approach would be valuable to economic-advisers and planning commissions to help bring realism into national policy-making, and the analysis of alternate development strategies and programs. The method that has been expounded here for its south-eastern region may be readily applied to all of Nabropat's comprehensive economic development plans, which would probably include a number of similar interdependent regional programmes. Even if the individual regional programmes may have little physical interdependence of other illustrated in the example, they would be most intimately and intricately interdependent in respect of different resources and basic industry outputs: (1) all types of expert, professional, skilled, semi-skilled or unskilled manpower; (2) food supplies and other essential personal consumer goods; (3) essential medical, educational, transport, communications and administrative serivces; (4) basic resources that may be produced in the island, like cement, fertilizers, electricity; (5) capital goods, like turbo-generators, factory equipment and other heavy machinery etc., much of which may require importing. Above all else these intricate independencies would be reflected in the annual national budget in one form or another. All such requirements must be either produced locally or imported. All must be paid for in local or foreign currency. It would be possible to extract all the resource requirements over the plan period, in terms of manpower, materials and services from the Master Plan Networks for the separate

programmes, as described in this paper.

Networks provide data for plan evaluation based on simulation models.

The interdependent projects in each programme may then be regarded as a network of interlocking, interdependent investments, each with its own varying, extended gestation period, producing an output of some category that is required somewhere in the economy, during as well as beyond, the span of the plan period. Consequently, the variation of both inputs and outputs during the plan period would be tentatively determined as required in the plan. Similar projections of resource investment inputs and other material resources, and production outputs of all kinds may be made for all aggregate activities on the separate networks. The different categories of inputs and outputs must be aggreagted separately in order to avoid the simplification of allocating money only, in the implementation planning and programming process. These aggregate inputs and outputs would serve as input data for simulation models of the economy.

Simulation models could be formulated in such a manner as to explicitly incorporate these resource categories separately, depending on the purpose of each model. The models could then help to evaluate the implications and effectiveness of the proposed economic and fiscal policies in achieving plan objectives. Alternative policies and strategies may then be experimented with on the computer in order to evolve the best possible overall strategy and implementation process. Further, as plan-implementation advances, periodic evaluation of progress and revisions where desirable could be more readily effected, using the networks and the models. These

ideas and concepts have yet to be examined, experimented with and formulated more precisely. They are included here merely to stimulate thinking on means of bridging the "implementation gap" in the developing countries.

Modern Management Science and (Computer) Technology the best hope.

The developing countries are attempting to achieve in a decade, or even less in some instances, what the Western developed countries took over a century to accomplish by way of socio-economic development, but often with much less per capita resources and skills. Such a developmental feat is tantamount to telescoping, or compressing, time in human affairs more than tenfold. The feat becomes even remotely possible only when the judicious use of modern science and technology in the right amounts, at the right time and the right places, but above all else supported by the right kind of research, carried out indigenously as far as possible. Competent and highly efficient management at the national level becomes one of the pivotal skills in attempting such an enormous undertaking. It is efficient management above all else, that must first keep pace with the tenfold increase in the development-tempo, if the development-race against time is to be ever won. Yet competent managerial talent perhaps constitutes one of the most scarce of all resources in the developing countries.

Modern Management Science and computer technology have a vital role to play in assisting management to engineer the dynamic implementation systems and processes that the development feats being attempted call for. Simulation of such systems and processes on the computer could permit management to experiment with new ideas within a few days as compared to the years and decades that the real-life processes require. Thus managerial

judgement could be enhanced, making up for the scarcity of the rare talent, and the tempo of operations could be progressively increased to that which the desired development-tempo demands. Here again extensive research must pave the way for such a breakthrough, but that research must be conducted as far as possible indigenously in the developing countries, but supported directly by research in the developed countries.

The developed countries are making tremendous progress in the application of modern science and technology to developing fantastic systems of massive destruction, national defense, and space travel. This writer believes that if, for instance, the same imagination, initiative, talent, resource, sense of urgency, and national purpose that is now motivating and expediting the race to the moon, is brought to bear on the problems of International Economic Development, the objectives of the United Nations Development Decade could well be achieved in the next ten years. Bridging the "implementation gap" by using critical path network theory, followed by the application of more sophisticated management science and (computer) technology in progressive stages, seems to offer the best hope for initiating just such an imaginative effort, at the present time.

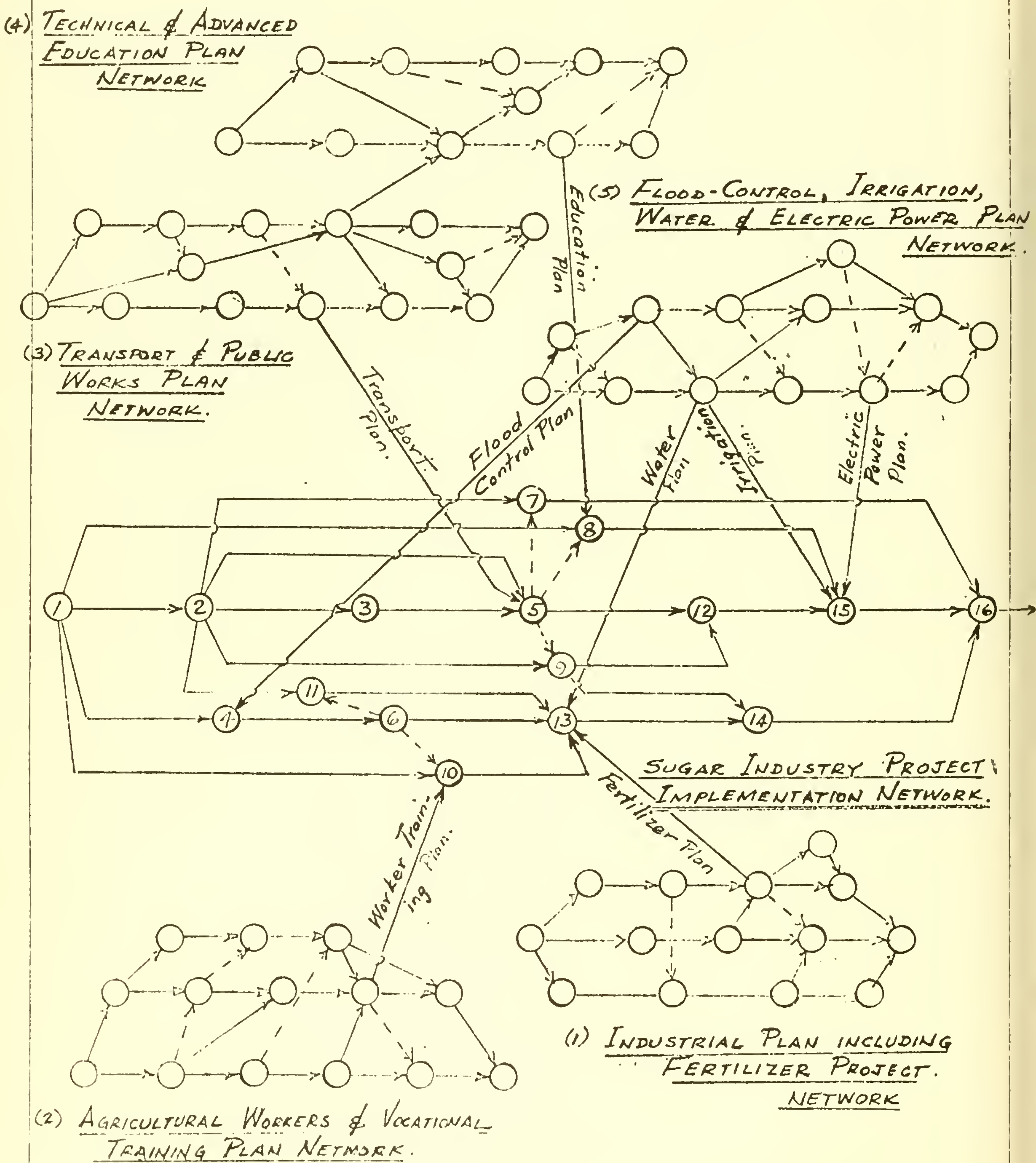


FIGURE 10: INTEGRATION OF SUGAR INDUSTRY PROJECT WITH OVERALL DEVELOPMENT PLAN FOR S.E. NABROPAT.

APPENDIX

INTEGRATION OF ALL PROJECTS INTO COMPREHENSIVE MASTER PLAN FOR DEVELOPMENT

Evolution of summarized Aggregate Network possible.

Figure 10 shows the integration of the Sugar Industry Project into the Overall Development Plan for S.E. Nabropat. Besides the implementation-network for the Sugar Industry Project, five other hypothetical networks depict: (1) the Industrial Plan including Fertilizer Project; (2) the agricultural and Vocational Training Plan; (3) the Transport and Public Works Plan; (4) the Technical and Advanced Adult Education Plan; (5) the Flood Control, Irrigation, Water and Electric Power Supply Plan. Considera-tion of time and space prevent elaboration on the integrated programme. However, the interdependencies between the various plans are at once apparent. Each plan could be analyzed independently as discussed in the foregoing paper and a summarized, simplified network becomes feasible. Such a network need only include activities and events of immediate concern to the Planning Commission for Nabropat and not all the details of each separate plan. The secret, if any, lies in aggregating the various activities to suit the purposes of the top planners and implementors only. From such an integrated plan for the region, a Master Financial Plan may be evolved for integrating the financing of regional development plans and programmes into the annual budget as well. Again, time and space prevent the elaboration of this idea in the present paper.

The implications of uncertain activity-durations and their relations to cost have not been discussed at all. The Program Evaluation and Review Technique (PERT) advocated by the U.S. Department of Defense uses three

time activities - an optimistic, a most likely and a pessimistic - and elaborate statistical probability methods in evaluating projects feasibility and progress, where uncertainties are involved as in Research and Development. This writer does not beleive that application of the probabalistic aspects of PERT have any immediate advantages to offer in the bridging the "implementation gap" in the developing countries. However, they may present some interesting possibilities to theoreticians where relevant, accurate statistics are available. Against the background of the broad overall possibilities of applying Critical Path Network Theory in bridging the "implementation gap" this writer can conceive of writing another paper, or even a book, entitled "Towards a Theory for Implementation of Development Plans, using Critical Path Network Theory."

In closing, a quotation from the Third Indian Five Year Plan might be appropriate to indicate the urgent need for developing a theory for the implementation of development plans: "...A statement of its objectives and targets can scarcely convey the scope and range of the tasks which the nation has undertaken to fulfill during the next five years. In the last analysis the Plan rests on the belief that the requisite effort will be forthcoming and that, at each level in the national life , within the limits of human endeavor, an attempt will be made to implement it with the utmost efficiency..." In its Memorandum on the Fourth Five Year Plan of October, 1964, the Government of India Planning Commission says: "...The Fourth Plan will present tasks of greater magnitude and complexity than those of the Third. As part of the preparation for the Fourth Plan, it is imperative that each agency at the Centre and in the States should undertake a systemmatic review of its organization, programme for training

and development of personnel, methods of planning, delegations of power and functions, and relationships to other agencies with which its operation have to be integrated...should be supported by carefully worked out administrative and operational plans which specify tasks and responsibilities, define their sequence and provide for effective supervision and control...Such administrative planning should precede the acceptance of...proposals for the Fourth Plan. All essential preparatory steps should be initiated now. ...The Committee of Administration...has been asked to formulate detailed proposals for strengthening administration and Plan implementation..." The writer beleives that this paper provides the basic ideas and theory with which the urgent implementation problems of India, and those confronting all developing countries, can be approached with new hope for their successful resolution.

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